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Systematic meta-review of supported self-management for asthma: a healthcare perspective

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ABSTRACT

Background: Supported self-management has been recommended by asthma guidelines for three decades; improving current sub-optimal implementation will require commitment from professionals, patients and healthcare organisations. The PRISMS meta-review and RECURSIVE health economic review were commissioned to provide a systematic overview of supported self-management to inform implementation. We sought to investigate if supported asthma self-management reduces use of healthcare resources and improves asthma control; for which target groups it works, which components, and which contextual factors contribute to effectiveness. Finally, we investigated the costs to healthcare services of providing supported self-management.

Methods: We undertook a meta-review (systematic overview) of systematic reviews updated with randomised controlled trials (RCTs) published since the review search dates; and health economic meta-analysis of RCTs. Twelve electronic databases were searched in 2012 (updated in 2015; pre-publication update January 2017) for systematic reviews reporting RCTs (and update RCTs) evaluating supported asthma self-management. We assessed the quality of included studies and undertook a meta-analysis and narrative synthesis.

Results: 27 systematic reviews (n=244 RCTs) and 13 update RCTs revealed that supported self-management can reduce hospitalisations, Accident and Emergency attendances and unscheduled consultations, and improve markers of control and quality of life for people with asthma across a range of cultural, demographic and healthcare settings. Core components are patient education, provision of an action plan and regular professional review. Self-management is most effective when

delivered in the context of proactive long-term condition management. The total cost (n=24 RCTs) of providing self-management support is offset by a reduction in hospitalisations and A&E visits (standard mean difference 0.13 (95%CI -0.09 to 0.34)).

Conclusions: Evidence from a total of 270 RCTs confirm that supported self-management for asthma can reduce unscheduled care and improve asthma control, can be delivered effectively for diverse demographic and cultural groups, is applicable in a broad range of clinical settings, and does not significantly increase total healthcare costs. Informed by this comprehensive synthesis of the literature, clinicians, patient interest groups, policy-makers and providers of healthcare services should prioritise provision of supported self-management for people with asthma as a core component of routine care.

Systematic review registration. RECURSIVE: PROSPERO CRD42012002694 PRISMS: PROSPERO does not register meta-reviews

Background

Asthma is common (334 million people worldwide), responsible for substantial morbidity and an increasing burden on healthcare services globally.[1] In the UK, there are over 6 million primary care consultations, and 100,000 hospital admissions each year, at an estimated cost of £1billion a year.[2]

For a quarter of a century,[3] national and international guidelines have recommended – unequivocally – that people with asthma should be provided with self-management education reinforced by a personalised asthma action plan and supported by regular review,[4,5] though mode of delivery, personnel delivering the support, targeted group, and the intensity of the intervention will vary.[6] The 2014 UK National Review of Asthma Deaths provided a stark reminder of the importance of ensuring that people with asthma respond in a timely and appropriate manner to deteriorating symptoms: only 23% had documented evidence of having been provided with self-management education and 45% of people who died had not sought or received medical attention in their final attack.[7]

However, despite self-management being highlighted as a core component of all models of care for people with long-term conditions (LTCs) [8-10] and the concept being well established in the context of asthma,[4,5] in practice only a minority of people with asthma have an action plan.[11] Effective implementation requires a whole systems approach; combining active engagement of patients, with training and motivation of professionals embedded within an organisation in which self-management is valued.[12] Patient organisations, healthcare professionals, policy-makers, commissioners and providers of healthcare services thus need an up-to-

date systematic overview of the evidence to inform decisions about prioritisation of supported self-management and to underpin implementation strategies within diverse healthcare systems.

The data presented in this paper are derived from two parallel programmes of work on supported self-management in LTCs commissioned by the National Institute of Health Research: Practical Systematic Review of Self-Management Support (PRISMS)[13] and Reducing Care Utilisation through Self-management Interventions (RECURSIVE).[14] In the context of asthma, our overviews aimed to answer questions of importance to clinicians, patient interest groups, managers responsible for developing healthcare services and policy-makers: can supported self-management reduce use of healthcare resources and improve asthma control? More specifically, in which target groups has it been shown to work, which components are important, in what healthcare contexts, and at what cost?

METHODS

We used established methodology for undertaking a meta-review of systematic reviews (PRISMS) and a systematic review of randomised controlled trials (RCTs) (RECURSIVE).[15] The PRISMS and RECURSIVE reviews were undertaken during 2012-2013 with initial searches completed in November 2012 and May 2012 respectively. We updated the PRISMS searches in March 2015 with a pre-publication update in January 2017, and the RECURSIVE searches in September 2015. RECURSIVE is registered on PROSPERO: (CRD42012002694). (PRISMS could not be registered because PROSPERO does not register meta-reviews).

Search strategy

Table 1 summarises the PICOS criteria, search strategies and sources, search dates; further details are in Additional file 2. The PRISMS search strategy involved searching nine electronic databases using the terms: 'self-management support' AND 'asthma' AND 'systematic review' terms. We defined self-management as "the tasks that individuals must undertake to live with one or more chronic conditions. These tasks include having the confidence to deal with medical management, role management and emotional management of their conditions".[16] For the update, we searched not only for systematic reviews published after our initial search date but also for RCTs published after the search dates used by the included systematic reviews (See Additional file 1 for the details of these dates). Included systematic reviews were grouped according to the populations studied (children, adults, or ethnic minority groups) and the search dates of the reviews extracted. Dates for update RCT search were set from the date of the latest review search within each population group.

The RECURSIVE search strategy in nine databases was: “self-management support” AND “long-term condition” AND “healthcare use” AND “randomised controlled trial”. (RECURSIVE included asthma and other LTCs in a single search) We also specifically sought health economic publications linked to included RCTs.

Identification of relevant papers

Table 2 summarises the PRISMS and RECURSIVE processes. Following training (repeated cycles of duplicate screening of 100 titles, team discussion and clarification of exclusion rules), one reviewer (HLP or GP for PRISMS; LD for the update; MP for RECURSIVE) reviewed titles and abstracts and selected possibly relevant studies. A random sample of titles and abstracts (10% in PRISMS; 40% in RECURSIVE) was examined by a second reviewer (HP for PRISMS; PB or NS for RECURSIVE) working independently as a quality check. The agreement was 97% for the initial search and 99% for the update in PRISMS and 87% for the initial search and 88% for the update in RECURSIVE.

After a similar training process, the full texts of all potentially eligible studies were assessed against the eligibility criteria (see Additional file 3) by one reviewer (HLP for PRISMS; LD for update; MP for RECURSIVE). Second reviewers undertook checks: PRISMS 10% check (HP); RECURSIVE 30% check (PB or NS) achieving 83% and 85% agreement respectively. Disagreements were because unclear papers were included by the reviewer pending discussion with a lead investigator Uncertainties and disagreements were resolved by full team discussion.

Assessment of methodological quality

We used the R-AMSTAR (Revised Assessment of Multiple Systematic Reviews [17]) quality appraisal tool to assess the methodological quality of the systematic reviews included in the PRISMS study. This reflects both the quality of the review process, and the rigour with which the review assessed the quality of the studies they included. We used the Cochrane Risk of Bias tool to assess the quality of RCTs included in the updated search.[15] Quality assessment was undertaken by HLP or LD and independently by a second reviewer (HP) with disagreements resolved by discussion within the team (EE, GP, HLP, ST and HP).

To reflect both quality and size of the review, we developed a star weighting system based on a) the R-AMSTAR score (≥31 was defined as 'high-quality') and b) number of participants (≥ 1000 participants was defined as 'large')

*** Large high-quality review

** Either small high-quality review or large low-quality review

* Small low-quality review

In the RECURSIVE study, quality assessment of formal economic evaluations was undertaken using the Drummond checklist;[18,19] RCTs reporting healthcare utilisation were assessed by judging allocation concealment (the quality component most associated with treatment effect[20]) as adequate or inadequate according to the Cochrane Risk of Bias tool.[15]

Outcomes

The primary outcome in the PRISMS meta-review was unscheduled use of healthcare resources (specifically unscheduled consultations, accident and

emergency (A&E) department attendances and hospital admissions). Other outcomes of interest were asthma control, asthma-related quality-of-life, and process outcomes (specifically ownership of action plans). Healthcare utilisation rates and costs were the primary focus of the RECURSIVE review, especially major cost drivers (i.e. hospitalisation rates and costs) and comprehensive summaries including multiple sources of cost. The results of formal cost-effectiveness, cost-utility and cost-benefit analyses were also of interest.

Extraction of data

Data for the PRISMS review were extracted by HLP and LD (update) using a piloted data extraction form and checked independently by HP for integrity and accuracy. Disagreements were resolved by team discussion. We extracted data on: review rationale, the self-management intervention under review, review methodology, summary details of included RCTs (participant demographics, comparison groups, settings, service arrangements, components, duration/intensity of the intervention, follow-up arrangements) and the results of meta-analyses and narrative syntheses. We extracted the findings and conclusions as synthesised by the authors of the systematic reviews, specifically avoiding going back to the individual primary studies. The RCTs in the update review were extracted using similar headings.

A piloted data extraction sheet was devised for RECURSIVE that included: descriptive data (characteristics of studies, populations, and interventions) and quantitative data (for use in meta-analyses). All the descriptive data and approximately 40% of the quantitative data were double-extracted by two members of the research team working independently.

Data analysis

Meta-analysis is inappropriate at meta-review level due to the overlap of included RCTs between reviews. However, for the primary outcome, where two or more systematic reviews (including the RECURSIVE meta-analyses) present pooled statistics, we displayed the results graphically by creating 'meta-Forrest plots'. We undertook narrative syntheses to answer our key questions: Does supported self-management reduce use of healthcare resources and improve asthma control? For which target groups does it work? Which components contribute to effectiveness? In what contexts does supported self-management work? We categorised the reviews and RCTs included in the PRISMS meta-review according to the question(s) that they answered (see Tables 3 and 4: column 3) and synthesised the findings within these categories.

The final question (What is the effect of self-management on health care utilisation and costs?) was answered by a meta-analysis of the RECURSIVE RCT data. The primary analysis explored whether self-management support could reduce utilisation without compromising outcomes. Standardised mean differences (SMD) were computed using a random effects model meta-analysis due to anticipated heterogeneity. Four meta-analyses examined the effects of self-management support interventions on hospitalisation rates, A&E attendances, quality-of-life and total costs, respectively. We then constructed permutation plots of the data from the subset of trials reporting both utilisation (hospitalisation rates, A&E attendances or total costs) and health outcomes (quality-of-life). Further details about the analytic approach are described in the RECURSIVE report.[14] Forest plots and permutation plots [21] for the subset of studies reporting both health outcomes and utilisation outcomes were constructed in STATA version 14.

Interpretation and end-of-project workshop

The PRISMS and RECURSIVE teams worked independently, but held regular teleconferences to enable synergies between the findings of the parallel reviews to be developed. Frequent meetings of the multidisciplinary teams aided interpretation of the emerging findings. Finally, we held an end-of-project stakeholder conference at which the findings and over-arching conclusions from PRISMS and RECURSIVE were presented to 34 multidisciplinary stakeholders including people with LTCs, clinicians, commissioners, providers of healthcare services and policy makers. Small discussion groups discussed and advised on practical implications for commissioning and providing services for people with LTCs.

Lay involvement

The PRISMS project (which reviewed evidence from 14 LTCs) benefited from a lay collaborator who was involved from the inception of the project. She and other lay representatives from a range of LTC interest groups (including Asthma UK) contributed both to an initial stakeholder workshop at which the choice of LTCs studied in the project and self-management interventions of interest were discussed. Lay members also participated in the end-of-project workshop (described above) which aided interpretation and guided dissemination. The PRIMER patient and public involvement group at the University of Manchester collaborated with the RECURSIVE project.

Updating of searches prior to publication

We updated our PRISMS searches in January 2017 by undertaking forward citation of the original included reviews using Web of Science. Forward citation has been shown to be an efficient and effective method of identifying relevant papers in systematic reviews of complex and heterogeneous evidence.[22] We considered it was very unlikely that a subsequent systematic review or RCT would be published without citing at least one of the previously published reviews. One reviewer (HP) undertook focused data extraction of key findings which were checked by MP. The additional data were added into the syntheses as appropriate. Had we identified studies that substantially changed our conclusions we planned to undertake full duplicate data extraction, quality assessment and revised our synthesis.

RESULTS

Description of the studies in the meta-review

Figure 1 illustrates the PRISMA flow chart for both reviews. After removal of duplicates, 9,632 references were identified from the initial PRISMS search and an additional 6,321 from the update search. From these a total of 25 systematic reviews,[23-47] were included in the PRISMS meta-review, representing data from 240 unique RCTs. Year of review publication ranged from 1995 to 2013, and included RCTs dated from 1979 to 2013. In addition we included 13 RCTs published since the last search dates of the included reviews (2010 for children; 2012 for adults; 2011 for ethnic groups. See Additional file 1 for details).[48-60] (For clarity we refer to these as "update RCTs"). A further two systematic reviews (which included a further 4 RCTs),[61,62] and six RCTs [63-68] were added after the pre-publication update. 24 RCTs were included in RECURSIVE with publication dates from 1993 to 2015.[49,69-91]

After excluding overlap, this represents 270 unique trials undertaken in at least 29 high or middle income countries: Argentina; Australia; Belgium; Brazil; Canada; Chile; Denmark; Finland; France; Germany; India; Israel; Italy; Jordan; Malaysia; Malta; Netherlands; New Zealand; Norway; Russia; Spain; Sweden; Switzerland; Taiwan; Trinidad; Turkey; UK; USA and Venezuela.

In the 18 systematic reviews that reported the duration of follow-up in their included RCTs,[23-25,27-29,33,35,38-40,42-47,61] the modal duration (in 10 of the reviews) was 12 months, with only 3% of reported RCTs falling outside the range of 3 to 24 months. The update RCTs had a similar profile, with 6 of 13 update RCTs having a duration of 12 months (range 3 to 30 months).

Study quality and weight of evidence

Taking into consideration both study quality and total population size, 10 PRISMS reviews received an evidence weighting of three stars,[27,31,32,36-38,40,41,43,46] 13 were weighted two star,[23-26,29,30,33-35,39,42,44,45] and two weighted one star.[28,47] Of the PRISMS update RCTs, four were judged to be at low risk of bias,[50-52,58] five at high risk of bias,[48,49,55,59,60] and in four the risk of bias was unclear.[53,54,56,57] Allocation concealment was judged as adequate in six of the 24 asthma studies included in the RECURSIVE review.[74,76,80,83-85] Study quality is indicated in the first columns of Tables 3, 4 and 5, with details of the quality assessments in Additional file 4.

Overview of presentation of results

Tables 3, 4, 5 and 6 provide summaries of the studies included in the PRISMS meta-review, update RCTs, the RECURSIVE review and pre-publication update with more detailed tables in Additional file 5.

Can supported self-management reduce the use of healthcare resources and improve asthma control?

Use of healthcare resources

Figure 2 is a meta-Forrest plot illustrating the meta-analyses (including three PRISMS 3* reviews and RECURSIVE) that report relative risks of admissions, A&E attendances and/or unscheduled consultations.[27,31,38] Treatment event rates

from the meta-analyses are in Table 7. These results suggest similar effects in adults,[38] children,[27] and mixed populations.[31]

Hospitalisations were reported in 12 reviews.[25-29,31,35,38,40,41,44,46] Six meta-analyses (four 3*; two 2*) showed that self-management support interventions led to fewer hospital admissions,[25-27,31,38,41] Six narrative reviews of variable quality, reporting heterogeneous interventions, showed inconsistent effects on hospitalisations.[28,29,35,40,44,46]

Ten reviews reported A&E attendances.[25-27,29,31,35,38,40,44,46] Four meta-analyses (three 3* [27,31,38] and one 2* [26]) reported a reduction in A&E attendances in the self-management intervention compared to control groups. Four narrative reviews (one 3*;[46] three 2*[25,35,44]) showed a reduction in A&E attendances in at least half of their included RCTs; one 3* review showed inconsistent results,[40] and one 2* review showed no benefit on A&E attendances.[29]

Of the eight reviews that reported unscheduled care,[24,27,28,31,34,35,43,44] three 3* meta-analyses reported fewer unscheduled consultations in participants who received a self-management intervention when compared to control.[27,31,43] Furthermore, three 2* narrative reviews reported that self-management reduced unscheduled care in at least half their included trials.[34,35,44] The remaining two small or poor quality reviews, had inconsistent results.[24,28]

Asthma control

Of the 10 reviews that reported measures of control,[24,28,30,31,34,35,38,41,44,46] three meta-analyses (two 3* [31,41],one 2* [24]) and three narrative reviews [28,35,44] reported a reduction in symptoms in participants who received self-management interventions compared to control groups. The other four narrative reviews (two 3* [30,34],two 2* [38,46]) had inconsistent results [30,34,38] or showed no benefit on symptom control.[46] The broader concept of quality-of-life was reported as improved in some reviews,[25,30,34,46] but not others.[27,29,40,44]

Six reviews reported reduction in days missed from school or work.[24,29-31,38,41] Two 3* meta-analyses,[31,41] two small reviews each with only one RCT,[24,29] and five of the 13 RCTs in a 2* narrative synthesis of school-based interventions [30] concluded that self-management interventions reduced absenteeism. A single RCT reported in a 3* narrative review in adults concluded that asthma education following A&E attendance had no effect on absenteeism.[38]

In which target groups has supported self-management been shown to work?

The systematic reviews encompassed a broad range of populations in diverse healthcare and demographic settings with consistently positive findings. For example, the reviews included all ages,[28,31] or only children, [24,26,27,29,30,35,40,41] or adults.[34,38,43,46] Some focused on lower socioeconomic groups,[35,40] or ethnic minority communities.[25,29,35] The reviews and RCTs identified in the PRISMS update typically built on this extensive generic evidence base and investigated interventions targeting specific groups such as urban,[52,54] rural,[53] deprived communities,[46,52,54] cultural groups,[46,54,55,60] adolescents,[48,54,56,57] or older adults.[49,51] Table 8

summarises the key strategies used in trials to tailor interventions, or their mode of delivery, to different groups.

Cultural groups

Four reviews explored the impact of self-management in cultural groups.[25,29,35,46] A 2* meta-analysis reported that culture-specific programmes reduced hospitalisations in children and improved quality of life in adults compared to generic interventions.[25] A 3* narrative synthesis, found only two RCTs testing culturally tailored interventions, one of which improved quality of life.[46] The involvement of community health workers reduced use of healthcare resources in two thirds, and improved symptoms in all the seven RCTs included in a 2* narrative review.[35] An in-patient visit from a lay educator to Black or Latino children improved self-efficacy and action plan ownership one month post-discharge.[66] In contrast, three generic interventions in US minority populations showed no improvement.[46] Update RCTs, some underpowered, in indigenous populations had inconsistent outcomes.[29,48,55,60]

A&E attendees

Two 3* meta-analyses demonstrated reduced use of healthcare resources (admissions, A&E attendances and unscheduled consultations) in adults recruited during an A&E attendance (n=13 RCTs),[38] and children with a history of A&E attendance in the previous 12 months (n=38 RCTs).[27] Neither review improved markers of asthma control,[27,38] though an update RCT in paediatric A&E

attenders (low risk of bias) found that children discharged with an action plan had fewer symptoms at 28 days compared to usual care.[50]

Specific age groups

School-based interventions,[30] often using Information technology-based programmes[30] or delivered by peers,[48,56] improved quality-of-life and, in some cases, reduced absenteeism.[30,48,56,61] Generic parenting skills initiatives improved self-efficacy in families struggling to manage young children with asthma, with inconsistent effect on asthma outcomes. [64,67]

Two update RCTs reported interventions in older people that improved control and quality-of-life,[49,51] and one reduced use of unscheduled care.[49] A key feature of both complex interventions was a structured approach to tailoring in order to meet personal goals or address individual problems.

Which components of supported self-management are important?

A 3* meta-analysis (36 RCTs; 6,090 participants of all ages recruited from primary and secondary care settings) defined optimal self-management as education including advice on self-monitoring, a written action plan and supported by regular professional review.[31] There is evidence that reducing the intensity of self-management education or level of clinical review may reduce its effectiveness.[36]

Components of an action plan.

The components of an action plan have been further defined in two 3* and three 2* reviews.[23,24,32,36,39] In adults, self-monitoring based on peak flow or symptoms

is equally effective.[32,36,39] In a comparison in children, symptom-based plans were more effective at reducing unscheduled healthcare,[23] and equally effective at improving most measures of asthma control; the exception was days with symptoms, which were reduced more by peak-flow based plans.[23] A 3* review concluded that action plans including between two and four action points, including recommendations on increasing inhaled corticosteroids and initiating oral corticosteroids, were consistently effective in reducing admissions and A&E attendances.[32]

Behavioural change techniques

One 3* meta-analysis demonstrated that self-management interventions that incorporated specific behaviour change techniques reduced unscheduled care and improved control.[43] Meta-regression of the data from the 38 RCTs (7,883 participants) concluded that active involvement of participants was a key factor in reducing unscheduled healthcare.[43] More specifically, identifying individual behavioural traits (e.g. rebelliousness, low perceived emotional support) in adolescents enabled targeted use of behavioural change techniques.[54] A goal-setting approach proved challenging to implement in primary care settings.[63]

Technology

Two 1* narrative reviews investigated computer or internet-based interactive self-management programmes.[28,47] The effect on healthcare utilisation was inconsistent, confirmed by a recent review identified in the pre-publication update[62], though both showed improvement in symptoms [28] and/or quality-of-

life.[28,47] Two update RCTs of web-based self-management programmes for adolescents also showed improved asthma control,[54,57] and an extended follow-up of RCT participants concluded that these effects could be sustained 18 months after conclusion of the trial.[59] Several school-based interventions used technology-based interventions to improve control and reduce absenteeism.[30] Supported self-management using mobile phone technology currently has a limited and inconclusive evidence base,[42,45] though a recent RCT in pregnancy demonstrated improved asthma control and quality of life. [68]

Which contextual factors influence effectiveness?

Resonating with the concept of 'optimal' self-management (education, an action plan and regular review)[31] a 3* meta-analysis identified that omitting regular review [1 RCT] or reducing intensity of education [1 RCT] was associated with a smaller reduction in unscheduled consultations.[36] A 2* meta-analysis analysed the findings of 18 RCTs (3,006 participants) according to the components of the Chronic Care Model.[92] Interventions that included all four components, had a greater effect on adherence to inhaled corticosteroids compared to trials including self-management unsupported by the organisation components.[33]

Organisational role in promoting supported self-management.

A 3* narrative review of 14 RCTs (4,588 participants) concluded that proactive organisational systems can increase action plan ownership by promoting uptake of asthma reviews and implementing (and monitoring) structured management systems for asthma care.[37] A recent RCT of a structured approach to self-management

education in both primary care and specialist units improved asthma control and reduced unscheduled care,[65] and a large cluster RCT at low risk of bias increased adherence to guidelines and reduced asthma symptoms by systematically providing individualised prompts to general practitioners and parents of children with asthma.[52] Automatically linking an action plan to prescriptions given to patients being discharged from A&E improved clinician management and patient uptake of steroid courses.[50]

What is the effect of supported self-management on health care utilisation and costs?

The RECURSIVE meta-analysis confirmed that self-management support interventions for people with asthma are associated with significant improvements in quality-of-life outcomes (standardised mean difference (SMD) 0.26 (95%CI 0.12 to 0.39)); significant small decreases in hospitalisation rates and costs (SMD -0.21 (95%CI -0.40 to -0.01)); significant small decreases in A&E visits (SMD -0.25 (95% CI -0.49 to -0.01)); and non-significant small increases in total healthcare costs (SMD 0.13 (95%CI -0.09 to 0.34)). See Figure 3 for a Forrest plot of the total costs.

What is the evidence that supported self-management for asthma can reduce costs without compromising outcomes?

Figure 4 shows the overall permutation plot of the studies (n=21) reporting data on both quality-of-life and healthcare utilisation. The majority of the studies on quality-of-life versus costs related to hospitalisations and A&E attendances were in the right-down quadrant indicating cost-effectiveness (reduced healthcare utilisation and

improved quality-of-life). However, In terms of total costs (n=7), the picture was mixed with more studies around zero and the right-up quadrant indicating that similar costs or small cost increases are necessary to achieve better quality-of-life.

What is the evidence that supported self-management for asthma is cost-effective?

Four studies applied formal economic analyses; two showed that self-management support interventions were dominant (i.e. significantly better health outcomes with significantly lower costs),[72,86] and two produced non-significant ratios between costs and benefits at levels likely to appeal to decision-makers [75,89] (better outcomes with non-significant increases in costs) (see Additional file 5 for more details).

Thus, the benefits derived by supported self-management interventions are associated with reductions in key areas of healthcare utilisation such as hospitalisations and A&E attendances and can be delivered at similar levels of total costs to usual care.

DISCUSSION

Summary of findings

Extensive evidence (n=270 RCTs) derived from a broad range of demographic and healthcare settings, reveals that supported self-management can reduce hospitalisations, A&E attendances and unscheduled consultations, and improve markers of control and quality-of-life for people with asthma. Core components of effective self-management are education, provision of an action plan and the support of regular professional review. Effectiveness has been demonstrated in diverse cultural, clinical and demographic groups, with evidence that tailored programmes have greater impact than generic interventions. A range of modes of delivery (including telehealthcare) may be employed to suit preferences and context. The cost of providing self-management support is offset by a reduction in hospitalisations and unscheduled healthcare.

Interpretation of findings

The literature on asthma self-management is particularly well developed and may thus be an exemplar for other LTCs.[13-14] The 16 systematic reviews reporting effectiveness were typically large (five included data from more than 5,000 participants[27,30,31,41,43]) and had consistently positive results suggesting a mature evidence-base, unlikely to be influenced by further trials. Outcomes in sub-groups were more often the subject of the update RCTs as the field moves on from demonstrating overall effectiveness to investigating the impact in specific target groups,[48-58,60,61,72] demographic contexts,[52-54,66] or mode of delivery.[54,59,62,72]

Self-management support for asthma is a complex intervention and successful interventions were multi-component including education, trigger avoidance, teaching self-monitoring, optimal treatment strategies, promotion of adherence, and behaviour change techniques many of which are common to self-management in other LTCs.[6] Appropriately in a variable condition,[4] the hallmark of asthma self-management is the provision of an action plan with advice on recognising and responding to deterioration in control.[4,32] People with asthma, however, have broader concerns as they accommodate the condition within their lives and the action plan needs to be embedded in support for 'living with asthma'.[93]

Individuals' with LTCs adjust medical regimes and self-management strategies to fit into their own lives and health beliefs.[13] Meta-reviews, for example in type 2 diabetes,[94,95] hypertension,[96] and asthma [25] have emphasised the importance of culturally-tailored interventions. Self-management support may be provided by many different professionals – often specialist nurses[38,63] or LTC educators[25,27,95] – but in some contexts community health workers[35,97] or peer counsellors [30,56,66] were the key personnel. Traditionally education is delivered face-to-face, but increasingly technology-based interventions are being developed as alternatives.[27,28,30,42,45,47,54,57,59,62,68]

Self-management support interventions are an integral component of high quality care for people with LTCs.[8-10] Several of the systematic reviews demonstrated the synergy between self-management education and regular clinical review.[31,33,36] and supported self-management is most effective when delivered within a proactive asthma management programme,[33,37,65] or integrated within organisational systems.[50,52] Only a minority of trials had follow-up periods over 12

months, and studies are needed to confirm long-term sustainability. Costs associated with self-management interventions are similar to usual care.

Strengths and limitations

Meta-reviews have some intrinsic strengths and limitations. The methodology enables the efficient review of a large body of evidence and thus provision of a comprehensive overview to inform policy and practice. However, it relies on the quality of systematic reviews (e.g. comprehensive search strategies; accurate – data extraction and synthesis). We used the validated R-AMSTAR instrument to assess the quality of included systematic reviews.[17] In contrast to GRADE[98] (now recommended by the Cochrane Handbook[15]) R-AMSTAR assesses overall quality of the review, rather than assessing the quality of evidence individually for each outcome.

Re-synthesis of materials already synthesised risks further loss of detail and potential for erroneous assumptions, especially if the primary focus of the review did not directly align with the questions of the meta-review. Overlap between the RCTs included in the systematic reviews may result in undue emphasis on commonly cited papers.

Whilst some reviews and update RCTs directly compared interventions with/without specific components,[23-25,32,36,39,43] or a specific mode of delivery,[28,29,41,45] often the different interventions were compared to usual care allowing only indirect comparison.[31,33,35,37,42,46,47] A further limitation is that 'usual care' is rarely defined in RCTs,[99] and the definition is even more unclear at meta-review level.

Typically usual care is enhanced in the context of a trial, reducing the apparent impact of an intervention.[100]

Systematic reviews are only as current as their most-recent search, and meta-reviews add an additional time delay. In the PRISMS meta-review we therefore not only updated our search for systematic reviews, but also searched for RCTs published after the date of the last search used by the included systematic reviews. In addition, prior to publication we undertook forward citation on all the included systematic reviews, which identified two recent systematic reviews and six RCTs.[61-68] None of these changed our conclusions, confirming the maturity of the evidence base.

Screening and data extraction were not conducted by two reviewers working independently, however, both projects ensured all the reviewers were fully trained and instituted random checks at every stage. Restricting inclusion to reviews with extractable RCT data maintained the quality of evidence, but may have resulted in some lower-grade but useful evidence being rejected.

RECURSIVE was not restricted to formal cost-effectiveness studies – it had a broader focus and included studies reporting data on health care utilisation only, without a full effectiveness analysis including costs and quality of life. Some of the RCTs in the RECURSIVE meta-analysis used more comprehensive definition of 'total costs' (e.g. based on societal perspective) compared to others; to account for this inconsistency, we also present the results on key sources of costs such as hospitalisation and A&E attendance rates.

The PRISMS and RECURSIVE teams worked independently, but met regularly throughout the studies to optimise synergies. A further strength was the

multidisciplinary team, including backgrounds in public health, general practice, epidemiology and health psychology, enabling a balanced interpretation.

CONCLUSIONS

Supported self-management for asthma can reduce unscheduled care, improve asthma control and quality-of-life and does not lead to significant increases in total health care costs. Effective self-management should be tailored to cultural, clinical and demographic characteristics and is most effective when delivered in the context of proactive LTC management. Healthcare organisations should prioritise and promote the provision of supported self-management for people with asthma.

List of abbreviations

A&E	Accident and emergency
LTC	Long-term condition
RCTs	Randomised controlled trials
SMD	Standardised mean difference
SR	Systematic review

Ethics approval: Not applicable: meta-review of published data

Consent for publications: Not applicable: no individual person's data

Availability of data and materials: Not applicable: all data used in this meta-review are derived from published studies and thus already available

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Author contribution: ST and HP initiated the idea for the PRISMS study, led the development of the protocol, securing of funding, study administration, data analysis, interpretation of results and writing of the paper. CG and AS were grant holders on the PRISMS review who contributed to the development of the protocol, the securing of funding, the interpretation of results and the writing of the paper. EE, HLP and GP were systematic reviewers who undertook searching, selection of papers and data extraction with ST and HP. LD undertook the updating of the PRISMS review.

PB developed the idea for the RECURISVE study, secured funding and had the primary responsibility for the interpretation of the results and writing the paper. MP and PB reviewed articles, extracted the data, undertook the data analysis and wrote the RECURSIVE paper. MP performed the RECURSIVE update for this meta-review.

All authors had full access to all the data, and were involved in interpretation of the data. HP wrote the initial draft of the paper with HLP, LD, MP and ST to which all the authors contributed. ST and HP are study guarantors for PRISMS; PB and MP are study guarantors for RECURSIVE.

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FIGURES AND LEGENDS

Figure 1. PRISMA flowchart

Note: The initial RECURSIVE search included all long term conditions: Papers reporting asthma RCTs were identified from 184 studies included in the full RECURSIVE report.[14]

Figure 2. Meta-Forrest plot of healthcare resource use from meta-analyses.

This meta-Forest plot displays the summary data from the PRISMS systematic reviews that reported relative risk (RR). Note that meta-analysis is inappropriate at meta-review level due to the overlap of included RCTs between reviews.

Figure 3. Meta-analysis of total costs

Figure 4. Permutation plot

Quality of life (axis x) and hospitalisations (axis y blue) and total costs (axis y- red).
In this permutation plot, the effects of self-management interventions on outcomes (quality-of-life) and utilisation (hospitalisations and total costs) can be visualised simultaneously by placing them in quadrants of the cost effectiveness plane depending on the pattern of outcomes. Such plots identify studies in the appropriate quadrant (i.e. those that reduce costs without compromising outcomes) and those in problematic quadrants (i.e. those that reduce costs but also compromise outcomes, or those that compromise both outcomes and costs).

Table 1. PICOS search strategy and sources for the reviews

	PRISMS systematic meta-review	RECURSIVE systematic review
Population	Adults/children with asthma, from all social and demographic settings. Multi-condition studies if asthma data reported.	Adults (≥18 years) with asthma (within a wider search of long-term conditions), excluding studies in the developing world.
Intervention	Self-management support interventions	Self-management support interventions
Comparator	Typically 'usual care', or less intense self-management interventions.	Typically 'usual care' or less intense self-management interventions.
Outcomes	Unscheduled use of healthcare services (admissions, A&E attendances, unscheduled consultations), health outcomes (asthma control), quality-of-life, process outcomes (ownership of Action plans, self-efficacy).	Healthcare utilisation with comprehensive measures of costs or major cost drivers (i.e. hospitalisation, A&E attendances). Quality-of-life
Settings	Any healthcare setting	Any healthcare setting
Study design	Systematic reviews of RCTs. RCTs published after the date of the last search in the included systematic reviews (see Additional file 1).	RCTs
Dates	Initial database search: January 1993 (3 years before the publication of the earliest systematic review identified in scoping work) to July 2012. Manual and forward citations were completed in November 2012. Update search: March 2015.	Initial database search: inception to May 2012. Update search: September 2015
Databases	MEDLINE, EMBASE, CINAHL, PsycINFO, AMED, BNI, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, and ISI Proceedings (Web of Science).	CENTRAL, CINAHL, EconLit, EMBASE, Health Economics Evaluations Database, MEDLINE, MEDLINE In-Process & Other Non-Indexed Citations, NHS Economic Evaluation Database and the PsycINFO
Manual searching	Systematic Reviews, Health Education and Behaviour, Health Education Research, Journal of Behavioural Medicine, and Patient Education and Counseling.	Systematic reviews
Forward citations	On all included systematic reviews. Bibliographies of eligible reviews.	None
In progress studies	Abstracts were used to identify recently published trials	Abstracts were used to identify recently published trials
Other exclusions	Previous versions of updated reviews. Papers not published in English.	Not applicable

Table 2. PRISMS and RECURSIVE processes for selection of studies, quality assessment, data extraction, analysis and interpretation.

	PRISMS systematic meta-review	RECURSIVE systematic review
Title and abstract screening	Initial training One reviewer selected studies for full text screening Quality check: Random sample of 10% checked independently by second reviewer. Agreement: 97% for the initial search and 99% for the update Uncertainties resolved by discussion	Initial training One reviewer selected studies for full text screening. Quality check: Random sample of 40% checked independently by second reviewer. Agreement: 87% for the initial search and 88% for the update Uncertainties resolved by discussion
Full text screening	Following training, one reviewer selected possibly relevant studies for inclusion. Quality check: Random sample of 10% checked independently by second reviewer. Agreement: 83% Uncertainties resolved by discussion	Following training, one reviewer selected possibly relevant studies for inclusion. Quality check: Random sample of 30% checked independently by second reviewer. Agreement: 85% Uncertainties resolved by discussion
Quality assessment	Duplicate quality assessment using: R-AMSTAR [17] for systematic reviews ('high-quality' defined as ≥31), combined with size of the review ('large' defined as ≥1000 participants) to give star rating (1* to 3*) Cochrane Risk of Bias tool for RCTs.[15] Disagreements resolved by discussion	Duplicate quality assessment using: Drummond for economic evaluations.[18,19] Allocation concealment for RCTs Disagreements resolved by discussion
Data extraction	Data extraction by one reviewer Quality check: 100% checked for accuracy by a second reviewer. Disagreements resolved by discussion	Data extraction by one reviewer Quality check: Random sample of 40% extracted independently by second reviewer Disagreements resolved by discussion
Analysis	Reviews/RCTs categorised according to the question(s) that they answered • Does supported self-management reduce healthcare utilisation and improve control? • For which target groups does it work? • Which components contribute to effectiveness? • In what healthcare contexts does supported self-management work? Meta-Forrest plots for pooled statistics of the primary outcome (healthcare utilisation) Narrative synthesis within categories.	Meta-analysis: Standardised mean differences (random effects model) to examine the effects of self-management support interventions on hospitalisation rates, A&E attendances, quality-of-life and total costs. Permutation plots of the data from of trials reporting both utilisation (hospitalisation rates, A&E attendances or total costs) and health outcomes (quality-of-life).
Interpretation	Monthly teleconferences to enable synergies between PRISMS and RECURSIVE End-of-project stakeholder conference to discuss findings and implications for commissioning and providing services for people with LTCs	

Table 3. Summary table of findings of PRISMS systematic reviews and their relevance to the meta-review questions

Reference & weighting. n RCTs, n participants, R-AMSTAR Date range RCTs	Comparison	Relevance to meta-review questions What is the impact? Target groups? Which components? Context?	Interventions included	Target group(s)	Synthesis	Main results
** **Bailey 2009** [25] 4 RCTs; 617 participants, R-AMSTAR 36 RCTs 2000-2008	Culturally-orientated programmes vs.Usual care or limited / generic education. FU (mode) 12m range 4-12m	**Target:** Ethnic groups	Education, action plans, triggers and avoidance, collaboration with healthcare services. Language-appropriate asthma educators.	Minority groups: Puerto Rican; African-American; Hispanic; Indian sub-continent. Adults and children.	Meta-analysis Narrative analysis	Reduced hospitalisation in children [RR: 0.32 (95%CI 0.15 to 0.70) 1RCT] but not reported in adults Improved QoL in adults [WMD 0.25 (95%CI 0.09 to 0.41)] [2 RCTs] 2 of 2 RCTs reported a reduction in A&E visits, and hospitalisations: one reported no difference in 'use of healthcare resources' 2 of 3 reported improved QoL (adults)
** **Bernard Bonnin 1995** [26] 11 RCTs; 1,290 participants, R-AMSTAR 27 RCTs 1981-1991	Interactive teaching on self-management vs. Standard care.	**Target:** Children	Interactive teaching (one-to-one or group) to support asthma self-management.	Children: aged 1 to 18y. Overall severity classified as 'mild to moderate'	Meta-analysis Narrative analysis	Reduced hospitalisation [ES: 0.06 (+/- -.08)] and emergency visits [ES 0.14 (+/-0.09)] [5 RCTs] Children with high baseline numbers of hospitalisations and emergency visits had greatest subsequent reduction in morbidity.
** **Bhogal, 2006**[23] 4 RCTs; 355 participants, R-AMSTAR 41, RCTs 1990-2004	Symptom-based written PAAPs. vs Peak flow-based PAAP FU (mode) 3m range 3-24m	**Target**: Children **Components:** PEF vs symptom monitoring	Asthma education plus PAAPs for both parents and children. Generally contained 3 steps: often employing 'traffic lights'. Monitoring varied: either daily or when symptomatic.	Children aged 6 -19 yrs with mild to severe asthma.	Meta-analysis	Symptom-based PAAPs reduced unscheduled care compared to peak-flow-based PAAPs [RR 0.73 (95%CI 0.55 to 0.99)] [4 RCTs] No difference in hospital admissions [RR 1.51 (95%CI 0.35 to 6.65)] Peak flow-based PAAPs reduced the number of symptomatic days/week [mean difference: 0.45 days/week (95%CI 0.04 to 0.26)] [2 RCTs] No significant difference for adult or child QoL
** **Zemek 2008** [24] 5 RCTs; 423 participants	Written PAAPs vs. No PAAP Symptom-based vs.	**Impact** **Target:** Children **Components:** PAAP	Education for parents and children, plus PAAPs, with 3 steps: often employing 'traffic lights'.	School-aged children with mild to severe asthma	Meta-analysis	A PEF-based PAAP reduced unscheduled care compared to no plan: [WMD -0.50 (95%CI -0.83 to -0.17)][1 RCT] A PEF–based PAAP compared to no plan reduced symptom scores: [WMD -11.80 (95%CI -18.22 to -5.38)] and mean difference of school

R-AMSTAR 41; RCTs 1990–2005	PEF-based PAAP FU (mode) 3m range 0.5-24m		Monitoring varied: either daily or when symptomatic.			days missed [WMD -1.03 (95%CI -1.85 to -0.21)] [1 RCT]
***Boyd 2009 [27] 38 RCTs, 7,843 participants R-AMSTAR 39, RCTs 1985 - 2007	Education targeting children/parents vs. Low intensity education. FU (mode) 12m range 4-12m	**Impact** **Target:** Children, A&E attendees	Education plus: therapy review; self-monitoring; PAAPs; trigger avoidance. Range of settings and professionals and mode of delivery	Children (0 – 18y of age) who had attended A&E for asthma within the previous 12m.	Meta-analysis Sub-group analyses	Education reduced A&E attendances: [RR 0.73 (95%CI 0.65 to 0.81) 17 RCTs], admissions [RR 0.79 (95%CI 0.69 to 0.92) 18 RCTs] and unscheduled consultations [RR 0.68 (95%CI 0.57 to 0.81) 7 RCTs] No effect on QoL: [WMD 0.13 (95%CI 0.73 to 0.99) 2 RCTs]. Sub-group analyses (type and timing of intervention, timing of outcome assessment, or age of participants) did not change findings.
*Bussey Smith 2009 [28] 9 RCTs, 957 participants, R-AMSTAR 26, RCTs 1986 - 2005	Computerised education vs. Traditional self-management FU (mode) 12m range 3-12m	**Impact** **Components:** Technology-based interventions	Interactive computerised educational asthma programmes (games tailored to the individual; web-based education; interactive communication devices)	Patients (3 – 75y). 7 RCTs in children, 2 in adults. 4 RCTs in urban or inner-city populations	Narrative analysis	1 of 4 improved hospitalisation, and 1 of 5 reduced unscheduled care. 5 of 9 studies found statistical improvements in asthma symptoms compared to control.
**Chang 2010 [29] 1 RCT, 113 participants R-AMSTAR 40; RCT 2010	Education by IHWs (Indigenous healthcare workers) vs. Education no IHW FU 12m	**Impact** **Target:** Ethnic groups	Initial clinical consultation, reinforced by home visits from a trained IHW. Personalised, child-friendly, culturally-appropriate education materials.	African-American and Hispanic communities. Children aged 1-17y. Mean age approx. 7y.	Narrative analysis	There was no effect on hospitalisations: [OR 1.58 (95%CI 0.37 to 6.79)] or A&E attendances: [OR 0.30 (95%CI -0.17 to 0.77)] [1 RCT] Days absent from school were reduced by 21% in the intervention group (95%CI 5-36%) [1 RCT] Carer asthma-QoL was not significantly different: [0.25 (95%CI -0.39 to 0.89]
**Coffman 2009 [30] 18 asthma RCTs, 8,077 participants, R-AMSTAR 29; RCTs 1987-2007	School-based asthma education vs. Usual care	**Impact** **Target:** School-children	School-based education on asthma, medication, monitoring, avoiding triggers. Delivered by nurses; health educators; peer counsellors; teachers; +/- computer programmes	Children (4 – 17y) Severity: mild to severe, majority were black or Latino.	Narrative analysis	Unscheduled healthcare was not reported. School absences significantly reduced in 5 of 13 RCTs. Days with symptoms were reduced in 3 of 8 RCTs. Nights with symptoms improved in 1 of 4 RCTs: 1 found improvement in control group. QoL improved in 4/6 RCTs.
***Gibson 2002 [31] 36 RCTs, 6,090 participants	Self-management programmes vs. Usual care	**Impact** **Components:** Regular review **Context:** LTC care	Education (100%); self-monitoring of symptoms or PEF (92%); regular review by a medical practitioner (67%); PAAP (50%). Sub-	Adults and children. Range of settings including: hospital; emergency room; out-patients;	Meta-analysis	Self-management reduced hospitalisations [RR 0.64 (96%CI 0.50 to 0.82) 12 RCTs], A&E visits [RR 0.82 (95% CI 0.73 to 0.94) 13 RCTs], unscheduled consultations [RR 0.68 (95% CI 0.56 to 0.81) 7 RCTs] Self-management reduced days off work/school [RR 0.79 (95% CI 0.67 to 0.93) 7 RCTs], and improved QoL [SMD 0.29 (95% CI 0.11 to

R-AMSTAR 39; RCTs 1986 –2001			group analyses based on these service models	community setting; general practice.	Sub-group analysis	0.47) 6 RCTs] Optimal self-management (supported by a PAAP and regular review) reduced hospitalisations [RR 0.58 (96%CI 0.43 to 0.77) 9 RCTs], and A&E visits [RR 0.78 (95% CI 0.67 to 0.91) 9 RCTs]
***Gibson 2004 [32] 26 RCTs, 6,090 participants R-AMSTAR 39; RCTs 1987 - 2002	Different components of written PAAPs vs. Usual care	**Components:** PAAPs	Complete PAAPs specified when/how to increase treatment (n = 17); incomplete omitted advice on increasing ICS (n=4); non-specific (n=5) only had general instructions	Adults and children. Variety of settings including: hospital; emergency room; outpatients; community setting; general practice.	Action points %predicted vs %best Treatment advice Non-specific plans	Benefits were found for any number of action points (2 to 4). Both reduced hospitalisations, but only % personal best reduced A&E visits. PAAPs which included advice on increasing ICS and starting oral steroids reduced hospitalisations, and A&E visits. Efficacy of incomplete and non-specific PAAPs was inconclusive.
**Moullec 2012[33] 18 RCTs, 3,006 participants R-AMSTAR 27; RCTs 1990 - 2010	Interventions to improve inhaled steroid adherence vs Usual care FU (mode) 12m range 0.25-24m	**Context:** LTC care	All studies included self-management; some included components of Chronic Care Model (CCM): decision support; delivery system design; clinical information systems.	Moderate - severe asthma (one RCT included COPD). Age (35 – 50y). Women over-represented.	Meta-analysis	Effect size for adherence to ICS compared by number of components of the CCM in the study: 1 CCM components (n=13): small ES 0.29 (95%CI 0.16 to 0.42) 2 CCM components (n=5): large ES 0.53 (95%CI 0.40 to 0.66) 3 CCM components (no studies) 4 CCM components (n=4) very large ES 0.83 (95%CI 0.69 to 0.98)
**Newman 2004 [34] 18 asthma RCTs (of 63 RCTs) 2,004 participants, R-AMSTAR 23; RCTs 1997 –2002	Self-management interventions vs. Standard care/basic information	**Impact**	Individual/group interventions, focussed on symptom monitoring, trigger avoidance and adherence to medication. A few used techniques to address barriers to effective self-management.	Adults with 3 LTCs (including asthma)	Narrative analysis and comparison between interventions	7 of 11 studies reported a reduction in unscheduled health care. 6 of 12 studies reported improved QoL 3 of 8 studies reported reductions in severity of symptoms all used education and action plans. 8 of 14 reported improved adherence
**Postma 2009 [35] 7 RCTs, 2,316 participants R-AMSTAR 23; RCTs 2004 - 2008	Community health worker (CHWs) vs. Usual care FU (mode) 12m range 4-24m	**Impact** **Target:** Ethnic groups, children	CHWs from the same community as participants. Education on asthma, lifestyle, trigger avoidance, with resources to reduce allergen exposure.	Children (5-9 yrs) with allergies, low-income, and mainly African American and Hispanic...	Narrative review	3 of 6 studies reported reduced hospitalisation, and reduced unscheduled consultations. 4 of 6 reported reduced A&E attendances 'Consistent and significant decrease in caregiver-reported asthma symptoms among intervention subjects compared with control subjects in 6 studies'

***Powell 2009** [36] 15 RCTs, 2,460 participants R-AMSTAR 34; RCTs 1990 - 2001	Self-management vs. Physician-reviewed management Comparison of modified PAAPs	**Components:** P□□, Regular review **Context:** LTC care	Self- vs physician adjustment of medication (n=6 studies) PEF vs symptoms PAAPs (n=6) Other variations (n=3)	Adults with asthma recruited from a range of primary, community, A&E, secondary care	Self- vs physician management Symptoms vs PEF Modified PAAPs	In 6 studies: 4: no difference in hospitalisation, 1: no difference in A&E visits, 3: inconsistent effects on unscheduled consultations. Of 6 studies, 6 reported no difference in hospitalisation, 5 reported inconsistent effects on A&E visits Omitting regular review [1 RCT] or reducing intensity of education [1 RCT] increased unscheduled consultations. Verbal (vs written) PAAPs had no effect on hospitalisations, or A&E visits. [1 RCT]
***Ring 2007** [37] 14 RCTs, 4,588 participants R-AMSTAR 35; RCTs 1993 - 2005	Interventions encouraging use of PAAPs vs. Usual care	**C□□□□□:** organisation of care	Interventions promoting PAAP ownership or use. Diverse interventions (educational; prompting; asthma clinics; asthma management systems; quality improvement)	Adults or children with asthma with moderate-to-severe asthma ; some post-exacerbation	Narrative analysis	4 of 5 studies of education, 1 of 2 studies of telephone consultations, 1 of 2 studies of asthma clinics, and 1 of 2 studies of asthma management systems reported increased PAAP ownership, 1 study of self-management education, 1 of 2 studies of telephone consultations, 1 of 2 studies of asthma management systems increased understanding/use of PAAPs.
***Tapp 2010** [38] 13 RCTs, 2,157 participants R-AMSTAR 39; RCTs 1979 - 2009	Asthma education at A&E visit vs. Usual care FU (mode) 6m range 2-18m	**Impact** **Target:** post A&E attendance	Asthma education provided by asthma or A&E nurses within a week of A&E visit included PAAPs; triggers; monitoring; inhalers; medication	Adults recruited during an A&E attendance.	Meta-analysis Narrative analysis	The intervention reduced hospital admissions [RR 0.50 (95%CI 0.27 to 0.91) 5 RCTs], A&E visits [RR 0.66 (95% CI 0.41 to 1.07) 8 RCTs] Effect on QoL (2 RCTs) was inconsistent. There was no effect on days off work/school.
***Toelle 2004** [39] 7 RCTs, 967 participants R-AMSTAR 38; RCTs 1990 - 2001	Written PAAP vs. No plan, Symptom vs. PEF based PAAP FU (mode) 12m range 6-12m	**Components:** PAAP	Peak flow based written PAAP or symptom-based written PAAP delivered in primary or tertiary care.	Adults (28 – 45y) and children in 1 RCT)	Meta-analysis Sub-group analysis	Unscheduled healthcare: assessed in 1 RCT, not reported by SR. No difference between symptom and peak flow based PAAPs in hospitalisations [RR 1.17 (95%CI 0.31 to 4.43) 3 RCTs] or A&E attendances [RR 1.17 (95% CI 0.31 to 4.43) 3 RCTs]. Symptom-based PAAPs were more effective at reducing unscheduled consultations [RR 1.34 (95% CI 1.01 to 1.77) 2 RCTs]
***Welsh 2011** [40] 12 RCTs, 2,342 participants, R-AMSTAR 41; RCTs 1986 - 2010	Home-based self-management vs. Routine care or general education FU (mode) 12m range 6-24m	**Impact** **Target:** Children	Language appropriate education (asthma, triggers, medication, inhalers, self-management with PAAPs). Also homework, technology devices, 24-hour hotline.	Children (mostly <12y, recent healthcare visit. Mainly ethnic and/or deprived communities in US	Meta-analysis Narrative analysis	No difference between groups in mean number of A&E visits [mean difference 0.04 (95%CI -0.20 to 0.27) 2RCTs)] 2 of 5 studies reported hospitalisation: one found a reduction and one an increase in the intervention group. Effect on A&E visits (6 RCTs) was inconsistent. Overall no effect on QOL was found in 5 studies.
***Bravata 2009**	Self-management	**Impact**	Self-monitoring or self-	Children (<18	Meta-analysis	Interventions targeting parents/caregivers reduced hospitalisation

[41] 63 RCTs,13,476 participants R-AMSTAR 40;. RCTs 1966-2006	Quality Improvement (QI) vs Other QI strategies	**Target:** Children	management. Patient / Caregiver education. Provider Education. Organisational change and Interventions with multiple QI strategies.	years).		rates by 1.2% per year (95% CI, 0.1 to 2.4%) n=5 Self-management intervention studies improved symptom-free days by 2.8% (95% CI 0.6% to 5%) = 0.8 days per month n=7; and reduced monthly school absenteeism by 0.4% (95% CI, 0%-0.7%) = 0.1 day per month n=16. Longer duration of intervention increased the effect on school absences.
***Denford 2013 [43] 38 RCTs, 7883 participants R-AMSTAR 36; RCTs 1993-2000	Asthma self care vs usual /less intensive intervention. FU (mode) 12m range 3-18m	**Impact** **Components:** Behaviour change	Commonest behavioural change techniques including: self-monitoring (n=30), instruction (n=27), goal setting (n=26), and inhaler technique (n=24).	Adults (18 and over) with a diagnosis of asthma.	Meta-analysis	Intervention group participants had reduced asthma symptoms [SMD= - 0.38, (95% CI -0.52 to 0.24) 27 RCTs] and unscheduled healthcare use [OR 0.71 (95% CI 0.56 to 0.9) 23 RCTs]. Increased adherence to preventative medication compared to control [OR 2.55 (95% CI: 2.11 to 3.10)16 RCTs]
**de Jongh 2012 [42] 1 asthma RCT (of 4) 16 participants R-AMSTAR 35; RCTs 1993–2009.	Mobile phone messaging for self-management vs Usual care range 4-12m	**Components:** Mobile phone messaging	Self-management interventions delivered by mobile phone messaging	Participants of all ages, gender or ethnicity. Included any LTC (one asthma study).	Narrative synthesis.	In the single asthma study, there were fewer admissions (2 vs 7) but more unscheduled consultations (21 vs 15) in the intervention group compared to the usual care group. The pooled asthma symptom score showed a significant difference between groups, favouring the intervention group (MD-0.36, 95%CI -0.56 to -0.17).
**Kirk 2012 [44] 10 asthma RCTs, 2,195 participants. R-AMSTAR 23; RCTs 1995-2010.	Self-care support vs Usual care FU (mode) 12m range 3-24m	**Impact** **Target:** Children	Interventions aiming to help children take control of and manage their condition, promote their capacity for self-care and / or improve their health.	Children (≤18yrs) with a LTC: asthma (10 RCTs), Cystic fibrosis (2), diabetes (1).	Narrative Synthesis	Of 8 RCTs, 2 reported fewer asthma admissions; 5 reported fewer A&E attendances and 2/3 reported fewer unscheduled consultations. Control improved in 5 of 8 RCTs. QoI improved in 2/5 RCTs
**Marcano-Belisario 2013 [45] 2 RCTs, 408 participants, R-AMSTAR 39; RCTs 2000-2013	Self-management APPs vs Traditional self-management FU 6m	**Components:** Smartphone Apps.	Self-management support interventions provided by smartphone app.	Adults with clinician diagnosed asthma	Narrative Synthesis.	Of 2 RCTs, 2 reported no difference in hospital admissions. 1 reported fewer A&E attendances compared to control 1 RCT found no difference in unscheduled GP consultations, or out of hours consultations, but reduced primary care nurse consultations. 1 study reported no difference in mean difference in Asthma Control Questionnaire scores between the intervention and control group at 6 months. 1 of 2 studies found improved QOL in the intervention group.
***Press 2012 [46]	Interventions targeted at ethnic	**Impact**	Interventions targeting ethnic populations in US.	Adults (18 or older). Ethnic minority	Narrative	An education intervention reduced A&E attendance in 2 of 4 RCTs

5 RCTs (of 15 studies), 1,459 participants. R-AMSTAR 34; RCTs 1950-2010	minority groups vs Usual care FU (mode) 6m range 0.25-32m	**Target:** Ethnic groups	15 were education-based; 9 were system-level interventions. 5 were culturally tailored and community-based; 10 were hospital based.	groups. 10 studies African Americans, 4 studies Latinos.	Synthesis	and hospital admissions in 2 of 3 RCTs Symptoms were not reduced in any of the 3 RCTs that measured control. QoL was improved in 3 of 4 RCTs that used an asthma-related QoL outcome..
Stinson 2009 [47] * 4 asthma RCTs (of 9 studies). 826 asthma participants. R-AMSTAR 28; RCTs 1993-2008.	Internet based self-management vs Usual care FU (mode) 12m range 3-12m	**Target:** Children **Components:** Internet based	Any internet based or enabled self-management intervention	Children (6-12) or adolescents (13-18) with LTCs: asthma (4 RCTs), pain (1), encopresis (1), brain injury (1), obesity (1).	Narrative synthesis.	1 RCT reported no difference in hospitalisations compared to control; 1 RCT reported significant reductions in A&E visits; and 1 of 2 RCTs showed fewer unscheduled consultations 4 out of 4 reported significant improvement in a measure of control. 1 of 4 asthma RCTs reported a significant benefit on QOL

Abbreviations: ES: effect size, FU: follow up, ICS inhaled corticosteroid, LTC: long-term conditions, OR: odds ratio, PAAP: Personalised Asthma Action Plan, PEF: peak expiratory flow, RR: risk ratio, QoL: quality of life, SMD, standardised mean difference, WMD, weighted mean difference, 95%CI: 95% confidence interval. d: day, w: week, m: month, y: year

Table 4. Summary table of findings of update RCTs and their relevance to the meta-review questions.

Reference & weighting. participants, Risk of bias	**Comparison and primary outcome**	Relevance to meta-review questions What is the impact? Target groups? Which components? Context?	**Study type and Interventions included**	**Target group(s)**	**Main results** **[1º] is defined primary outcome**
Al-Sheyab 2012 [48] n=261 HIGH risk of bias	Adolescent Asthma Action program vs Standard care	**Target:** Adolescents **Components:** Peer education	Cluster RCT. FU 3m Triple A. Peer leaders from year 11 were trained to deliver program to years 8, 9 and 10.	Adolescents in Jordanian high school. Intervention group had fewer females, less symptoms and higher English proficiency.	Compared to control improvements QoL improved [I: 5.42 (0.14) vs C: 4.07 (0.14) mean diff 1.35 1.04–1.76]
Baptist 2013 [49] n=70 HIGH risk of bias	Personalised asthma self-regulation intervention vs Education session	**Target:** Older adults **Components:** Health educator	RCT. FU 12m 6-session program (group /telephone). Patients selected an asthma-specific goal, and addressed potential barriers. Control is single session basic education + 2 telephone calls.	Aged 65 or older. Physician diagnosis of asthma, no restriction in severity. Majority Caucasian.	No between-group differences in A&E visits or hospitalisations. Healthcare utilization was lower at 6m, but not 12m Asthma control (ACQ) was similar at 1m and 6m. At 12m intervention group participants were 4.2 times more likely to have an ACQ score <0.75. [1º] QoL (mAQLQ) was significantly higher in the intervention group than in control at all time points (1m, 6m and 12m),
Ducharme 2011 [50] N=219 LOW risk of bias	'Take-home plan' post A&E visit with PAAP + prescription information vs Prescription but no PAAP/ information	**Target:** Children, A&E attendees **Components:** PAAP with prescription	RCT. FU 28d Intervention is written PAAP with a 'formatted' prescription for ICS (i.e. including information about use) issued by A&E doctor on discharge following asthma exacerbation.	Canadian children aged 1-17 recruited during A&E attendance for acute asthma (78% were under the age of 6y)	No between group differences in unscheduled care at 28d. Compared to control, at 28 days children given the PAAP had better asthma control. [Proportion with Asthma Quiz Score <2: I: 58% vs C: 41% RR 1.36 (1.04, 1.86)] No between-group difference in child/caregiver QoL at 28 days [1º] At 28 days adherence to ICS had declined from 90% (Day 1) to 50% at Day 14, with no significant group difference.
Goeman 2013 [51] n=114 Low risk of bias	Person centred education vs Written information.	**Target:** Older adults **Components:** Personalised education	RCT. FU 12m Personally tailored education session with asthma educator based on responses to a questionnaire. Inhaler technique	55 year or older, community based asthmatics with no restriction in asthma severity.	[1º] Compared to control group, at 12m the intervention group had better asthma control. [ACQ. Mean diff 0.3 (95% CI: 0.06–0.5); p = 0.01] and better asthma-related QoL (p = 0.01). No significant difference in number of steroid courses (p=0.17) At 12 m more intervention group participants (n=36, 61%) owned a PAAP compared to control (n= 21, 38%) p = 0.015

					[1º] Similar adherence to ICS at 12m (p = 0.015)
Halterman 2014 [52] N=638 LOW risk of bias	Personalised prompts for clinicians and parents, practice training and feedback vs Written guidelines	**Target:** Children, deprived communities **Components**: Feedback **Context:** Community based, clinical training	Cluster RCT. FU 6m Intervention practices received personalised clinician and parent prompts + blank PAAP; practice training; feedback Control practices sent guidelines.	Urban, primary care practices in deprived communities. Parents/children aged 2-12yrs with persistent poorly controlled asthma Recruited from waiting room over 4yr study	11% in both groups had an A&E visits or hospitalisation. [1º] Compared to control practices, at 2m children in the PAIR-UP practices had more symptom free days [I: 10.2 (SD4.8) vs C: 9.5 (5.1) d/2w (mean diff, 0.78; 95% CI, 0.29 to 1.27) but the difference was not significant at 6m. Nights with symptoms remained significant at 6m [I: 1.4 (3.0) vs C: 1.8 (3.2) mean diff: −0.43 (−0.77 to −0.09)]
Horner 2014 [53] N=183 UNCLEAR risk of bias	Asthma plan for kids vs Teaching on general health and well-being.	**Target:** Children, Rural communities	Cluster RCT FU 12m Programme delivered in 16 x 15min sessions, 3d a week for 5.5 weeks, by school nurses during lunch break + home visit	Grades 2-5 (Age 7-11). Physician diagnosis of asthma	No between group difference for admissions or A&E visits. No between group difference in QOL scores Inhaler skill improved in the intervention group compared to control after 4 months, and reported higher self-efficacy
Joseph 2013 [54] N= 422 UNCLEAR risk of bias	Web based asthma management intervention vs Control.	**Target:** Adolescents, Urban deprived, Ethnic groups **Components:** Web based, Behavioural change	RCT. FU 12m Internet based programme targeted at African Americans / urban adolescents with traits (low motivation; low perceived emotional support; resistance to change rebelliousness)	9 – 12 grade (14-18 years). Physician diagnosis of asthma and report >4 days of restricted activity in the past 30 days at baseline	No difference in reported A&E visits/hospitalisations at 12m. [1º] Compared to controls, at 12m the intervention group had fewer symptom days [RR 0.8 (0.6 to 1.0)] No difference in nights with symptoms; schooldays missed; days of restricted activity; days had to change plans Students characterised with rebelliousness or low perceived emotional support reported fewer symptom- days.
Khan 2014 [55] N=91 HIGH risk of bias	Asthma education + individualised written PAAP vs Asthma education (excluding PAAP)	**Target:** Ethnic group **Components:** Written PAAP	RCT. FU 6m Both groups receive individual asthma education during an OPD visit from a paediatrician + monthly FU. Intervention group trained in using a PAAP	1-14 years. Recruited via A&E OPD with partly controlled asthma (daytime or nocturnal symptoms, activity limitation, lung function < 80% best or exacerbation in previous year.)	[1º] There was a trend to improved outcomes at 6m but no significant between group difference in proportion of children attending A&E I:36 vs. C:52% (p=0.141) There was no between group difference in unscheduled doctor visits, asthma attacks, missed school days, night-time awakenings.
Rhee 2011 [56] N=112 UNCLEAR risk of bias	Peer led asthma education provided by peers at a day-camp. vs adult-led camp	**Target:** Adolescents. **Components:** Peer leaders	RCT FU 9m Asthma self-management skills + psychosocial skills taught at a day camp by peer leaders + monthly peer telephone contact Control: Similar education	13-17 years (including low income families). Mild/moderate/severe asthma. Asthma diagnosis for 1 year. Able to understand spoken and written English.	[1º] Both groups reported significantly increased quality of life over time (F=4.31, P=.002), with the intervention group having significantly higher quality of life at 6m (difference, 11.38; 95% CI, 0.96-21.79; P=.03) and 9m (12.97; 3.46-22.48; P=.008). Both groups reported improved attitude to asthma (F=11.94, P=.001); with greater improvement in the intervention group at

			delivered by adults. No phone.		6m (mean difference, 4.11; 95% CI, 0.65-7.56; P=0.02).
Rikkers Mutsaerts 2012 [57] N= 90 UNCLEAR risk of bias	Internet based self - management vs Usual care.	**Target:** Adolescents. **Components:** Internet based	RCT: FU 12m Internet based self-monitoring with algorithm-based advice Programme included: education (web-based + group), self-monitoring (FEV_1 + ACQ), PAAP and 3-6 m review.	12 – 18 years mild to severe persistent asthma on regular ICS medication and poorly controlled at recruitment	No between-group difference in exacerbations, physicians' visits or telephone contacts. [1º] Compared to control, QoL was better in intervention group at 3m [PAQLQ I: 6.00 vs C: 5.68 diff: 0.40 (0.17 to 0.62)] but not at 12m [I: 5.93 vs C: 6.05 diff: 0.05 (0.50 to 0.41) Compared to control, control was improved in intervention group at 3m [ACQ I: 0.96 vs C: 1.19 diff: -0.32 (-0.56 to -0.08)] but not at 12m [I: 0.83 vs C: 0.79 diff: -0.05 (-0.35 to 0.25)
Shah 2011 [58] N=150 GP s and 201 children LOW risk of bias	(General practitioner) GP training (PACE) vs No training	**Targets:** Children **Components:** GP training	Cluster RCT FU 12m GPs participated in 2x 3-hour workshops on communication and education strategies to facilitate quality asthma care	150 GPs and 221 children with asthma in their care	No between-group difference in hospitalization/A&E visits [I: 18% vs 12% diff 6% (− 4% to 15%)] No between-group difference in school absence or parent absenteeism for child's asthma [1º] Compared to controls, more patients of intervention group GPs had a PAAP [I: 61% vs 46% diff 15% (2% to 28%)
van Gaalen 2013 [59] N=107 HIGH risk of bias	Internet based Self - management vs Control. (FU of SMASHING trial)	**Target:** Adults. **Components:** Internet-based	RCT (FU study) FU 30m Education + PAAP, self-monitoring, and regular review The 200 patients in original 12m trial were invited for FU after 18m	Adults with asthma aged (18-50 years), using ICS 107/200 (54%) participated: I: 47/101 (47%) C: 60/99 (61%). Participants ACQ was similar, but AQLQ was greater than in non-participants.	At 30 months after baseline, there was a slightly attenuated improvement for both QoL [AQLQ adjusted between-group difference 0.29 [95% CI 0.01-0.57]) and ACQ (adjusted difference of -0.33 [95% CI -0.61 to -0.05]) scores in favour of the Intervention. No between group differences in FEV_1.
Wong 2012 [60] N=80 HIGH risk of bias	Symptom based written PAAP vs verbal counselling	**Target:** Children, Ethnic groups **Components:** Written PAAP	Single blinded RCT. FU 6m Intervention is symptom based PAAP given out at initial contact. Outcomes measured at baseline, 3, 6 and 9 months.	Malaysian children (mix of Malay, Chinese, and Indian) all severities of asthma. Ages 6-17 years. Recruitment process not described.	At 6m there was no difference in A&E/unscheduled care [I: 4 (10.8) vs C: 6 (21.1) p=0.35] At 6m there was no difference in proportion controlled [ACT≥20 I: 81% vs C: 87% p=0.50] or with no exacerbations [ACT≥20 I: 89% vs C: 82% p=0.62] or in QoL [mean PAQLQ I: 6.11 (0.88) vs 6.11 (1.09) p=0.99]

Abbreviations: ACQ: asthma congtrol questionnaire, ACT: asthma control test, C: control, FEV_1: forced expiratory volume in one second, FU: follow up, I: intervention, ICS inhaled corticosteroid, mAQLQ: mini Asthma-related Quality of Life Questionnaire, PAAP: Personalised Asthma Action Plan, PAQLQ: paediatric asthma-related quality of life, RR: risk ratio, QoL: quality of life, SD: standard deviation, 95%CI: 95% confidence interval. d: day, w: week, m: month, y: year

Table 5: Summary table of studies included in the RECURSIVE health economic analysis.

Reference. Country, Allocation concealment	Study type, number of participants, and Intervention(s)	Comparison & follow-up assessment	Target group(s)	Health economic results				Formal health economic evaluation
				Quality of life/asthma control	Healthcare utilisation (Hospitalisation)	Total healthcare costs	Unscheduled care	Cost effectiveness (Societal and health service perspective)
Baptist 2013 [49] **US** Concealment not adequate	RCT. n=70 Personalised 6-session self-regulation education	Usual care. FU: 12m	Older adults with asthma (> 65y). Mean age 74y. 14% male.	Proportion with ACQ <0.75, was greater in intervention group than controls (I: 13 (41.9%) vs C: 5 (15.6%)).	The intervention group had fewer hospitalisations (intervention: n=0; control n=4, p=0.04).	n/a	No difference in A&E visits (I: 1 vs C: 2 p=0.58) Intervention group had fewer unscheduled visits (I: 6 vs C:14, p=0.048).	n/a
Castro 2003 [69] **US** Concealment not adequate	RCT. n=96 Education, psychosocial support, PAAP and co-ordination of care.	Usual (private) primary care. FU: 12m	Inpatients, adults with asthma. Mean age 38y. 15% male.	No between group difference in mean AQLQ (I: 4.0 (SD1.3); vs C: 3.9 (SD 1.5) p=0.55.	Fewer admissions in Intervention group: re-admissions /patient (I: 0.4 (SD 0.9); vs C: 0.9 (SD=1.5); p=0.04.	Lower costs/patient I: $5,726 (SD 5,679) vs C: $12,188 (SD19,352) mean diff $6,462 p=0.03	No between group differences in number A&E visits/patient. I:1.9 (SD 4.3) vs CI: 1.4 (SD=1.5) p=0.52	n/a
Clark 2007 [70] **US** Concealment not adequate	RCT. n=808 Self-regulation intervention; nurse telephone-delivered	Usual care. FU 12m	Adult women with asthma. Mean age 49y. 100% female	No between group difference in mean AQLQ (I: 2.1 (SD=0.9) vs C: 2.1 (SD=0.9).	No between group difference in admissions /patient I: 0.2 (SD 0.7) vs C: 0.1 (SD 0.5)	n/a	Greater reductions in unscheduled visits (mean change: I: -0.63 (SD=2.4) vs C: -0.24 (SD 1.5)	n/a
de Oliveira 1999 [71] **Brazil** Concealment not adequate	RCT. n=52 Outpatient education programme, including a written PAAP.	Usual care. FU 6m	Adults; moderate to severe asthma. Mean age 38y. 15% male.	No between group differences in QoL score (I: 28 (SD 17) vs C: 50, (SD=15); p=0.0005).	No between group differences in admissions /patient (I: 0 vs C: 0.5 (SD 0.8); p=0.08).	n/a	Intervention group had fewer A&E visits/patient (I: 0.7 (SD=1.0) vs C: 2 SD=2).	n/a
Gallefoss 2001 [72] **Norway** Concealment not adequate	RCT. n=78 Group-plus individual self-management education with a written PAAP.	Usual primary care. FU 12m	Adults with asthma. Mean age 44y. 21% male.	Better QoLin Intervention group (SGRQ) at 12m (I: 20 (SD 15) vs C: 36.5 (SD 18); mean diff 16.3 (95%CI 16.3 to 24.4))	n/a	No between group differences in total costs (in NOK) I: 10500 (SD 20500) vs C: 16000 (SD 35400) p=0.510	**n/a**	Incremental SGRQ gain 16.3; Health costs difference NOK1900; All cost diff NOK -5500.
Gruffydd-Jones 2005 [73] **UK**	RCT. n=174 Targeted nurse-led telephone reviews	Usual primary care. 12 months.	Adults with asthma. Mean age 50y.	No between group difference in mean change ACQ. I: -0.11 (95%CI -032 to 0.11) vs	n/a	No between group difference in total costs. I: £209.85 (SD 220.94) vs C: £333.85 (SD 410.64),	n/a	n/a

Concealment not adequate	led including PAAPs.		40% male.	C: -0.18 (95%CI -0.38 to 0.02); p=0.349		mean diff £122.35; p=0.071		
Honkoop 2015 [74] **Netherlands** Adequate concealment	RCT. n=611 Nurse-led care to symptom control (I) [or FeNO controlled]	Usual care (partially controlled). 12 months.	Adults with asthma. Mean age 40yrs. 28% male.	No between group difference in EQ5D (QALYs) I: 0.91 vs C: 0.89, mean diff 0.01 (-0.02 to 0.04)	n/a	No between group difference in total costs I: $4591 vs C: $4180. Mean diff $411 (-904 to 1797) (p>0.05).	n/a	n/a
Kauppinen 1998 [75] **Finland** Concealment not adequate	RCT. n=162 Intensive education (use of inhaled drugs, PEF, monitoring and PAAP).	Conventional education. FU 12m	Adults, newly diagnosed asthma. Mean age 43yrs. 44% male.	No between group difference in 15D (I: 0.93, (0.90 to 0.94); C: 0.91 (0.8.9 to 0.94); p=0.47	n/a	Intervention had greater total costs than the control group I: £345 (247 to 1758) vs C: £294 (0 to 8078) (p<0.001).	**n/a**	Intensive education: incremental gain of 0.02 15D Incremental diff in health costs of £51.
Krieger 2015 [76] **US** Adequate concealment	RCT. n=366 Community Health Worker supported self-management	Usual care. FU 12m.	Adults with asthma. Mean age 41yrs. 27% male.	Intervention improved QoL. Mean change in miniAQLQ. I: 0.95 vs C: 0.36. diff 0.50 (0.28 to 0.71), p <0.001	No difference in mean change in number of urgent care episodes. I: -1.50 vs C: -1.60 diff 0.09 (-0.59 to 0.73) p=0.78.	n/a	n/a	n/a
Lahdensuo 1996 [77] **Finland** Concealment not adequate	RCT. n=122 Self-management, including breathing exercises, education, and PEF monitoring	Traditional treatment. FU 12m	Adults with asthma. Mean age 43yrs. 48% male.	Intervention improved QoL SGRQ (symptom domain) (I: 16.6 (SD=15.9) vs C:8.4 (SD=18.4). p=0.009	n/a	n/a	Intervention group had fewer unscheduled care visits/patient/year (I: 0.5 vs C:1 p=0.04)	n/a
Levy 2000 [78] **UK** Concealment not adequate	RCT. n=211 Structured education with PAAP by A&E specialist nurses.	Usual primary care. FU 6m	Adults with asthma. Mean age 40yrs. 43% male.	No between group difference in SGRQ (I: 30.25 vs C: 28.73. mean diff 1.52 (-4.05 to 7.09)).	No between group difference in hospital consultations (Median (IQR) I: 0 (1 to 3 vs C: 0 (1 to 6) p=0.17.	n/a	No between group difference in GP consultations (Median (IQR) I: 0 (1 to 7 vs C: 0 (1 to 7) p=0.14	n/a
Mancuso 2011 [79] **US** Concealment not adequate	RCT. n=296 Self-management workbook, behavioural contract, telephone calls.	Information/ PEF training. FU 12m	Adults attending A&E with asthma. Mean age 43yrs. 23% male.	No between group difference in change in AQLQ at 1y: I: 0.04 vs C: 0.18 mean diff 0.22 (-0.15 to 0.60)	n/a	n/a	No between group difference in proportion with A&E visits (I: 13% vs C: 11%)	n/a

McLean 2003 [80] **Canada** Adequate concealment	RCT. n=225 Pharmacist-led self-management, with PAAP.	Usual pharmacist care. FU 7m	Adults with asthma. Mean age 38yrs. 47% male.	Intervention improved QoL compared to control mean AQLQ (I: 5.13 vs C: 4.40, p=0.0001).	No between group difference in hospitalisations (I: 0.078 vs C: 0.16, p=0.94).	Intervention reduced total costs. (costs per patient I: $150; vs C:$351).	No between group difference in A&E visits (I: 0.04 vC: 0.21, p=0.48).	n/a
Moudgil 2000 [81] **UK** Concealment not adequate	RCT. n=689 Individual education and optimisation of drug therapy	Usual primary care. FU 12m	Adults with asthma. Mean age 35yrs. 47% male.	Greater improvement in QoLin intervention group (mean diff in change in AQLQ 0.22 (0.15 to 0.29)	No between group difference in hospitalisations (OR 0.51, (0.22 to 1.14)	n/a	No between group difference in A&E visits (OR=0.63 (0.23 to 1.68)	n/a
Piotto 2004 [82] **Australia** Concealment not adequate	Cluster RCT. n=170 Nurse-run asthma clinics including provision of PAAPs	Usual primary care. FU 9m	Adults with asthma. Mean age 50yrs. 48% male.	No between group difference in SGRQ (I: 27.3 vs C: 27.0. mean diff -0.5 (-4.0 to 2.9)	No between group difference in number admitted (I: 2; vs C: 0; p=0.499).	n/a	No between group difference in number attending A&E (I: 2; vs C: 0; p=0.499).	n/a
Pinnock 2003 [83] **UK** Adequate concealment	RCT. n=278 Nurse-delivered, routine telephone review.	Usual primary care. FU 3m	Adults with asthma. Mean age 57yrs. 41% male.	No between group difference in mini AQLQ (I: 5.17 C: 5.17 (mean diff 0.22 (-0.15 to 0.60).	No patients in either group had a hospital admission for asthma	n/a	No patients in either group had an A&E attendance for asthma	n/a
Price 2004 [84] **UK** Adequate concealment	Cluster RCT. n=1,553 Use of PAAPs with adjustable maintenance dosing.	Usual care FU 3m	Adults with asthma. Mean age 48yrs. 41% male.	No between group difference in proportion with improved QoL (I: 22.5%; vs C: 23.6%	No between group difference in hospital admissions (I: n=2; vs C: n=2).	Intervention reduced total costs. Cost/day/patient I: £1.13 vs C: £1.31. mean diff -£0.17 (0.11 to 0.23)	No between group difference in A&E visits (I: n=5; vs Cl: n=11)	n/a
Ryan 2012 [85] **UK** Adequate concealment	RCT. n=288 Mobile phone supported self-management.	Paper based PAAPs FU 6m.	Adults with asthma. Mean age 52yrs. 41% male.	No between group difference in mean change in mini AQLQ (diff -0.10 (-0.16 to 0.34))	No between group difference in hospital admissions for asthma (I: n=3; vs C: n=1).	n/a	No between group difference in A&E attendances for asthma (I: n=3 vs C: n=0).	n/a
Schermer 2002 [86] **Netherlands** Concealment not adequate	RCT. n=193 Guided self-management with education and PEF monitoring.	Usual primary care. FU 24m	Adults with asthma. Mean age 39yrs. 42% male.	No between group difference in total AQLQ (I:39 vs C: 29 (mean diff: 10 (-3 to 23).	No hospital admissions in either treatment group.	No between group difference in total costs I: 1,084 euro vs C: 1097 mean diff -13euros.	No A&E visits in either treatment group.	Incremental QALY gain 0.015. Incremental total cost €-13 euros ; Incremental health cost €11. Incremental health ICER €33/QALY.
Shelledy 2009 [87] **US**	RCT. n=166 Nurse (N) vs	Usual primary care.	Adults: A&E or admitted with	RT intervention group had greater change in	Intervention groups had fewer hospitalisations	Intervention groups had lower hospitalisation	No between group difference in A&E visits (I(RT): 0.09; I(N): 0.26	n/a

Concealment not adequate	respiratory therapist (RT) led education and management	FU 6m	asthma. Mean age 44yr. 22% male.	SGRQ I(RT) -11.0 vs I(N) -6.0 vs C: -2.5 (p<0.05).	(I(RT): 0.04; I(N): 0 vs C: 0.20; p<0.05)	costs (I(RT): $202; I(N): $0 vs C: $1,065; p<0.05)	vs C: 0.37	
Sundberg 2005 [88] **Sweden** Concealment not adequate	RCT. n=97 Interactive computer-based education plus nurse support.	Usual care. FU 12m	Young adults with asthma. Mean age 19yrs. 55% male	No between group difference in Living with Asthma Questionnaire I: 163.6 vs C: 166.2 p>0.05	No between group difference in hospital admissions (1 admission in each group).	n/a	No between group difference in A&E visits (I: n=17; C: n=16).	n/a
van der Meer 2011 [89] **Netherlands** Concealment not adequate	RCT. n=200 Internet-based self-management program, including electronic PAAP	Usual OP care. FU 12m	Adults with asthma. Mean age 37yrs. 55% male	No between group difference in EQ5D I: 0.93 vs C: 0.89. diff 0.006 (-0.042 to 0.054)	No between group difference in hospital admissions (mean cost: I: $571 vs C: $589 Mean diff $-17 p=0.95).	No between group difference in total healthcare costs (I: $2555 vs C: $2518, mean diff $-37 p=0.94).	n/a	Incremental QALY gain 0.024; Incremental total cost $641; Incremental health cost $37 Incremental health ICER $1541/QALY.
Yilmaz 2002 [90] **Turkey** Concealment not adequate	RCT. n=80 Outpatient clinic, special education programme.	Usual primary care. FU 36m	Adults with asthma. Mean age 29yrs. 37% male.	Intervention group had greater improvements in AQLQ (I: 197.1 vs C: 176.7; p=0.009	No between group difference in hospitalisations (I n=0; vs C: n=4).	n/a	Intervention group had fewer A&E visits (I: n=0; C:7; p=0.01).	n/a
Yoon 1993 [91] **Australia** Concealment not adequate	RCT. n=76 Brief, group-based, education with a PAAP	Usual OP care. FU 10m	Inpatient adults Mean age not reported 28% male.	No between group difference in QoL (I: 4.0 (SD 4.38) vs C: 3.96 (SD=3.34); p>0.05).	Fewer participants in the intervention group had hospital admissions (I: n=1; vs C: n=7, p<0.001).	n/a	No between group difference in A&E visits (I: n=3; C: n=7).	n/a

Abbreviations: A&E: accident and emergency, ACQ: asthma control questionnaire, AQLQ: asthma quality of life questionnaire, C: control, EQ5D: EuroQol five dimensions questionnaire, FeNO: fractional exhaled nitric oxide, FU: follow up, I: intervention, ICER: incremental cost-effectiveness ratio, IQR: interquartile range, n/a: not available, PAAP: Personalised Asthma Action Plan, PEF: peak expiratory flow, QALY: quality adjusted life years, QoL: quality of life, SD: standard deviation, SGRQ: St George's Respiratory Questionnaire, 95%CI: 95% confidence interval. d: day, w: week, m: month, y: year

Table 6. Focussed data extraction from additional studies identified by forward citation prior to publication

Reference n RCTs, n participants, Date range RCTs	Comparison	Relevance to meta-review questions What is the impact? Target groups? Which components? Context?	Interventions included	Target group(s)	Synthesis	Main results
Systematic reviews						
Coelho 2016 [61] 17 RCTs; 5879participants, RCTs 2005-2013	School-based asthma education vs. Usual care FU 'minimum 1m'	**Target:** Schoolchildren	Educational interventions to individuals, groups, or classes by healthcare professionals, teachers, educators, and/or IT	Schoolchildren with asthma and/or whole school	Narrative analysis	6/17 showed a reduction in unscheduled care 5/17 showed a reduction of the asthma symptoms; 5/17 reduced school absenteeism; 7/17 improved quality of life of the individuals. 8/17 showed that asthma education improved knowledge
McLean 2016 [62] 5 RCTs; 595 participants, RCTs 2011-2013	Interactive digital interventions (IDIs) vs Usual care FU 10 weeks – 12 months	**Impact** **Components:** Technology-based interventions	Interactive intervention (ie entering data, receiving tailored feedback, making choices) accessed through an 'app' that provides self-management information.	Adults (16 years and over) with asthma	Meta-analysis	Meta- analyses (3 studies) showed no significant difference in: Asthma control SMD 0.21 (95%CI -0.05 to 0.42); Asthma QoL SMD 0.05 (95%CI -0.22 to 0.32) but heterogeneity was very high. Removal of the outlier study reduced heterogeneity and indicated significant improvement for both asthma control SMD 0.54 (95%CI 0.22 to 0.86); asthma QoL SMD 0.45 (95%CI 0.13 to 0.77)
Randomised trials						
Hoskins 2016 [63] n=48	Goal setting + SM/PAAPs vs Usual care	**Components:** Goal setting	Practice asthma nurses trained in goal setting approach	Primary care patients due a review	Cluster feasibility RCT. FU 6m	Difficulty recruiting: 10/124 practices participated and 48 patients. No between group difference in QoL: mean diff mAQLQ 0.1 (I: 6.20 (SD 0.76) 95%CI 5.76 to 6.65 vs C 6.1 (SD 0.81) CI 5.63 to 6.57
Morawska 2016 [64] n=107	Generic parenting skills vs Usual care	**Components:** Parenting skills	Parenting skills for managing LTCs + asthma 'take home tips sheets'	Parents of children 2-10yrs with asthma and/or eczema	RCT. FU 6m	Between group improvement in parents' self-efficacy and childs' 'eczema behaviour', but not equivalent asthma outcomes. Parent and family generic QoL improved (p=0.01)
Plaza 2015 [65] n=230	Trained practices (I) vs specialist unit (I^s) vs Usual care (C)	**Impact:** **Components:** Education programme	Basic information on asthma, inhaler technique. provision of a PAAP	Adults with persistent asthma	Cluster RCT. FU 12m	The intervention groups had fewer unscheduled visits than control I:0.8 (SD 1.4) & I^s: 0.3 (SD 0.7) vs C:1.3 (SD 1.7) p=0.001, and greater improvements in asthma control (p=0.042) and QoL(0.019)

Rice 2015 [66] n=711	PAAP + in-patient lay educator vs PAAP	**Components:** Inpatient lay educator	Encourage FU attendance Build self-efficacy, set goals, overcome barriers	Children ages 2–17 years admitted with asthma	RCT FU 1m	No difference in attendance at FO appointment. Intervention group greater preventer use (OR 2.4, 95% CI 1.3 to 4.2); PAAP ownership (OR 2.0, 95% CI 1.3 to 3.0) and improved self-efficacy (p = 0.04).
Yeh 2016 [67] n=76	Family programme (+PAAP) vs Usual care (+PAAP)	**Components:** Family empowerment	Family empowerment to reduce parental stress, increase family functioning	Children age 6-12yrs with asthma	RCT FU 3m	Intervention families had reduced parental stress index (p=0.026) and improved family environment scores (p <0.0001); improved lung function, less disturbed sleep and cough but no difference in wheeze
Zairina 2016 [68] n=72	Telehealth supported PAAP vs Usual care	**Components:** Telehealth	Telehealth (FEV^1; symptoms) monitored weekly	Pregnant women with moderate/ severe asthma	RCT FU 6m	Telehealth improved ACQ: mean diff 0.36 (SD 0.15) 95%CI -0.66 to -0.07 and mAQLQ mean diff 0.72 (SD 0.22) 95%CI 0.29 to 1.16. No difference in perinatal outcomes.

Table 7. Treatment event rates from the meta-analyses

	Events/Total participants		Proportion participants with the event	
	Intervention	Control	Intervention	Control
Proportion hospitalised				
Boyd 2009	276/2009	351/2010	13.7%	17.4%
Gibson 2002	85/1200	139/1218	7.1%	11.4%
Tapp 2007	40/286	74/286	14.0%	25.9%
RECURSIVE	80/1727	124/1734	4.6%	7.2%
Proportion with A&E attendances				
Boyd 2009	337/1505	462/1503	22.4%	30.7%
Gibson 2002	291/1457	354/1445	20.0%	24.5%
Tapp 2007	74/472	104/474	15.7%	22.0
RECURSIVE	153/1171	227/1170	13.1%	19.4%
Proportion with unscheduled visits				
Boyd 2009	128/515	181/494	24.9%	36.6%
Gibson 2002	112/784	170/772	14.3%	22.0%

Table 8. Tailoring of self-management support for targeted populations

Group	Key strategies	Description of tailoring of self-management intervention	Relevant SRs/update RCTs	Evidence
Cultural groups	Cultural tailoring	Culturally-orientated self-management programmes including individual sessions with language-appropriate asthma educators, videos/ workbooks featuring culturally appropriate role models, education appropriate to socio-economic context, strategies for use of local healthcare services, asthma action plans.	****Bailey 2009** [25] Adults and children from minority groups	Culture-specific programmes for are more effective than generic programmes in improving QoL, knowledge, asthma control) but not all asthma outcomes.
		Culturally tailored, community-based interventions in which HCPs (pharmacists, asthma educator, social workers, respiratory nurses) provided language appropriate education programmes including health literacy-focussed teaching, use of videos, asthma physiology and management, inhaler technique, PAAP.	*****Press 2012** [46] Adults from minority groups in US	The five (of 15) education studies that were culturally tailored showed reduced use of unscheduled care and improved QoL, but this is not compared to non-tailored interventions
		Internet based programme developed to deliver education and a behaviour change intervention to African Americans adolescents. Strategies include voice-overs to accommodate literacy limitations, advice delivered by a 'disc jockey'	**(RCT) Joseph 2013** [54] Young teens	The intervention reduced symptom free days but had no effect on A&E visits/ hospitalisations.
	Community workers	Community health worker (CHWs) from the same/very similar community as participating families, provided individually tailored education at home visits. Topics included asthma, lifestyle, trigger avoidance, with resources to reduce allergen exposure, and smoking cessation support	****Postma 2009** [35] Ethnic minority children with asthma	Interventions involving CHWs reduced emergency and urgent care use in some, but not all the studies
		Indigenous healthcare workers (IHWs) provided personalised, child-friendly, culturally-appropriate education materials at home visits to reinforce clinical consultations.	****Chang 2010** [29] Ethnic minority children with asthma	The involvement of IHW in asthma programmes (1 RCT) improved control and QoL but not unscheduled care.
A&E attendees	Education during the A&E attendance	Education sessions conducted by asthma or A&E nurses, or less often respiratory specialists or a physiotherapist. Content varied usually including a triggers, PAAPs, and/or inhaler technique	*****Tapp 2010** [38] Adults A&E attendees	Educational delivered in A&E reduces subsequent hospital admissions but not A&E attendances. Effect on QoL was inconsistent
		PAAP, completed by the A&E physician, coupled with the prescription provided on discharge from A&E	**(RCT) Ducharme 2011** [50] Children aged 1-17 A&E attendees	Provision of a PAAP increased patient adherence to steroids (oral/inhaled), and improved asthma control
	Education after A&E	Education delivered by a healthcare professional or asthma educator shortly after an A&E attendance, including triggers, PAAPs, to child and their carers	***** Boyd 2009** [27] Children, A&E attendees	Asthma education reduced A&E attendances and admissions, but had no effect on QoL

School children	School-based programmes	School-based, group education, the majority including education for classmates without asthma.	****Coffman 2009** [30] Children	The intervention improves knowledge, self-efficacy, and self-management behaviors, but inconsistent effect on asthma control
		16 short group educational sessions, including strategies for problem solving, delivered in the school lunch break	**Horner 2014** [53] Grades 2-5 (Age 7-11)	Compared to generic health education, the intervention improved self-efficacy, but no effect on admissions or A&E visits or QOL
	Peer-led programmes	Year 11 pupils were trained to deliver the school-based asthma educational lessons to younger pupils	**Al-Sheyab 2012** [48] Adolescents	Compared to children in control schools, knowledge and QoL improved. Also increased self-efficacy to resist smoking
		Asthma self-management skills and psychosocial skills taught at a day camp by peer leaders followed by monthly peer telephone contact	**Rhee 2011** [56] 13-17 years	The intervention group had improved QoL and positive 'attitude to illness' compared to those attending adult-led camps
	Technology-based	Internet based interventions, delivered at home, clinic or school which delivered a psycho-educational programme involving information and skills training modules targeting improved health outcomes	****Stinson 2009** [47] Children 4-17yrs	The majority of studies reported improvement in symptoms, but impact on other outcomes was inconsistent.
		Theoretically based asthma computer programme with core modules (adherence, inhaler use, smoking reduction), with tailored sub-modules to address specific behavioural traits	**Joseph 2013** [54] 9 – 12 grade (14-18 years)	The intervention improved symptom control, but had no effect on A&E visits /hospitalisations.
		Internet-based self-management programme covering education, self-monitoring, an electronic action plan, and encouraging regular medical review. Supported by 2 face-to-face groups.	**Rikkers Mutsaerts 2012** [57] 12 – 18 years	Qol and asthma control improved compared to usual care, but no difference in use of healthcare resources.
Elderly	Goal-setting	Six-session programme, conducted by a health educator in groups (n=3) and telephone calls (n=3). Participants selected an asthma-specific goal, identified problems, and addressed potential barriers.	**(RCT) Baptist 2013** [49] Aged 65yrs or over	Compared to education alone, the intervention improved asthma control, and QoL, but not unscheduled care.
	Addressing individual concerns	Specific concerns, identified with the Patient Assessment and Concerns Tool (PACT), were addressed in an hour-long session. Both groups had standard education (inhaler technique, PAAP)	**(RCT) Goeman 2013** [51] 55 year or older	Compared to usual care, asthma control and QoL was improved by education tailored to individual patient concerns and unmet needs

Additional files

Additional file 1. Dates of initial and update searches

Additional file 2. Detailed search terms: PRISMS and RECURSIVE (all databases)

Additional file 3. Exclusion criteria: PRISMS and RECURSIVE

Additional file 4. Quality assessment and weighting: Table 4a) PRISMS systematic reviews; Table 4b) PRISMS randomised controlled trials; Table 4c) RECURSIVE randomised controlled trials.

Additional file 5. Characteristics of included studies and key outcomes: Table 5a) PRISMS systematic reviews; table 5b) PRISMS randomised controlled trials; Table 5c) RECURSIVE randomised controlled trials.

Figure 1

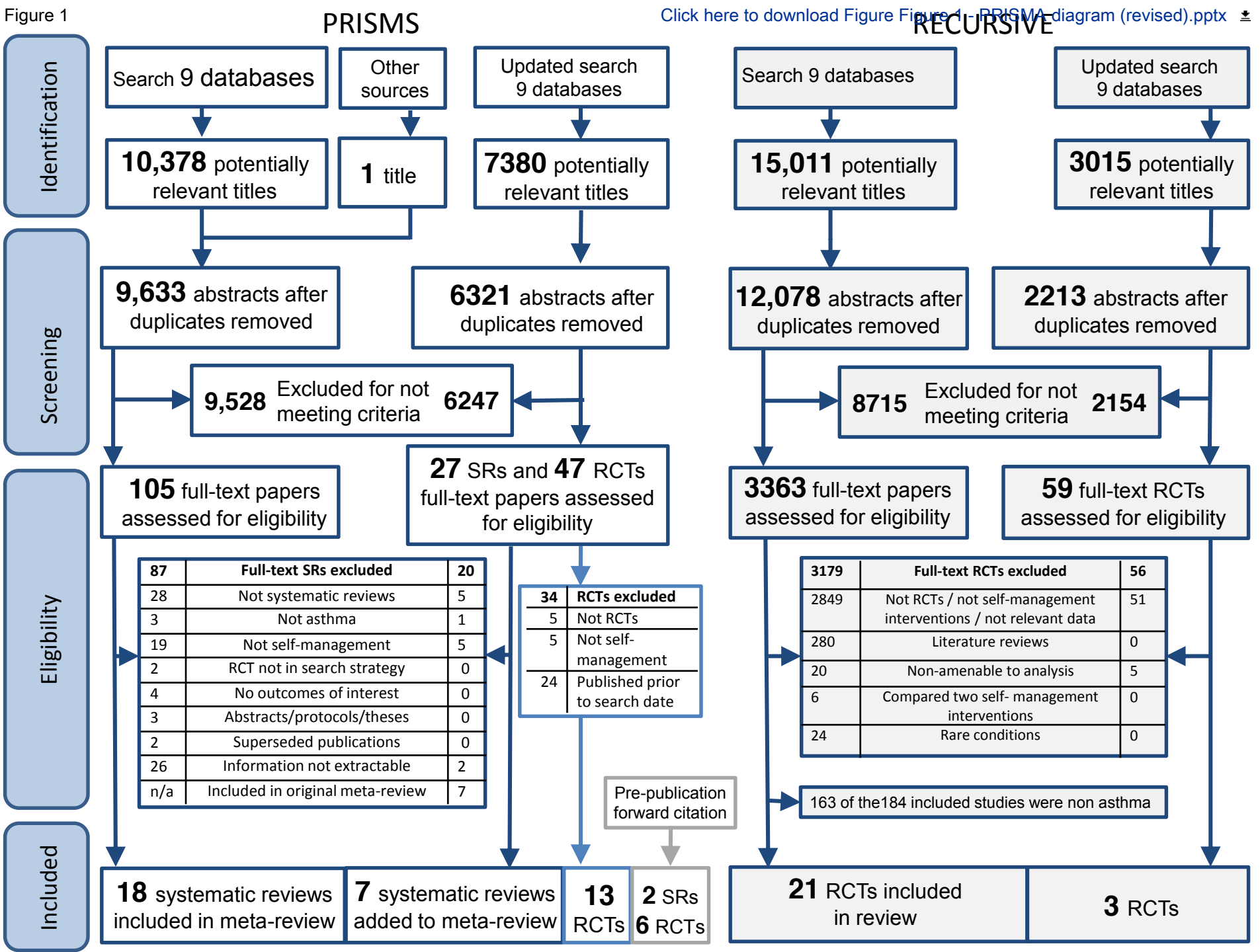

Figure 2. Meta Forrest plot of the meta-analyses that report relative risks of unscheduled care

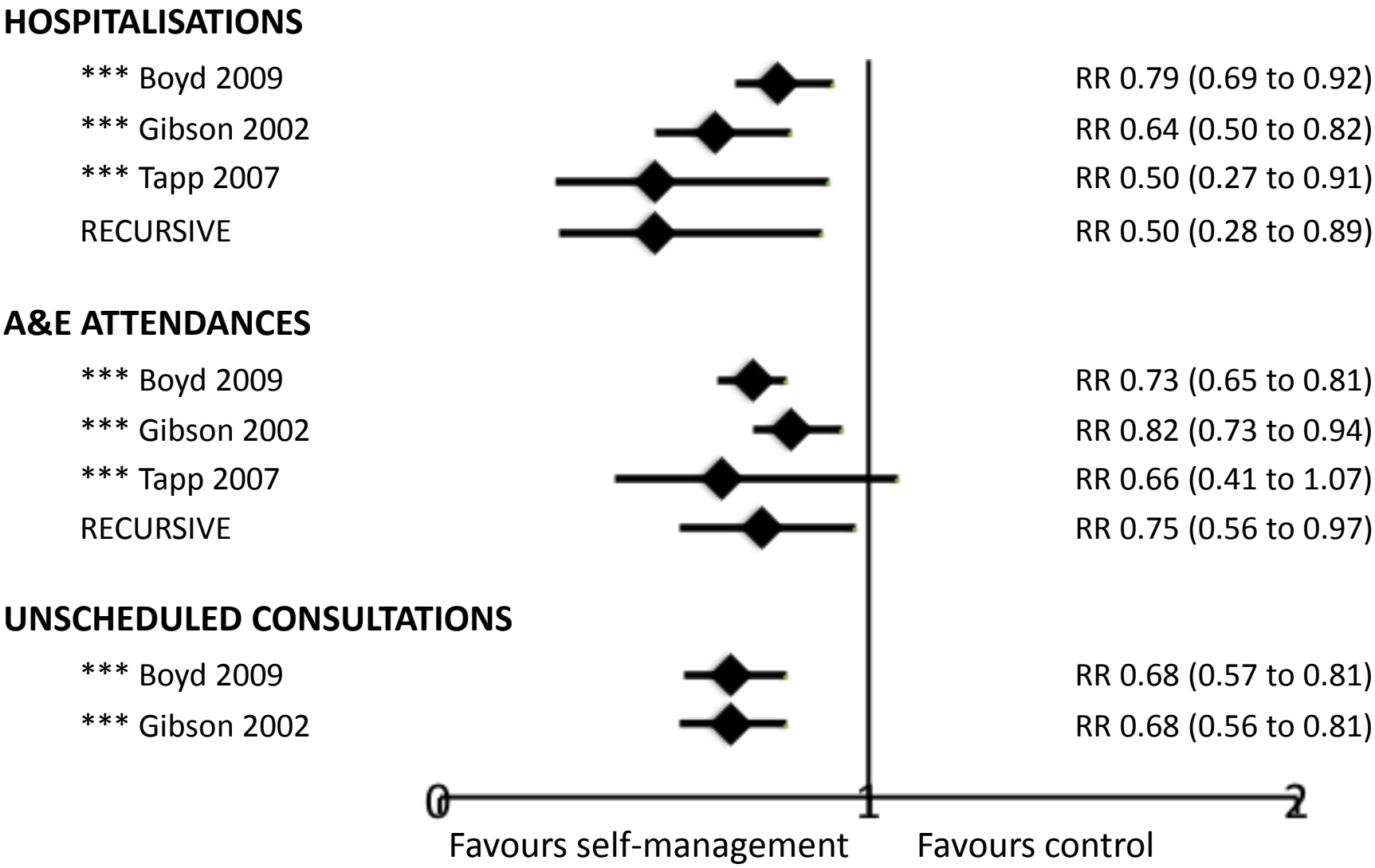

Figure 4

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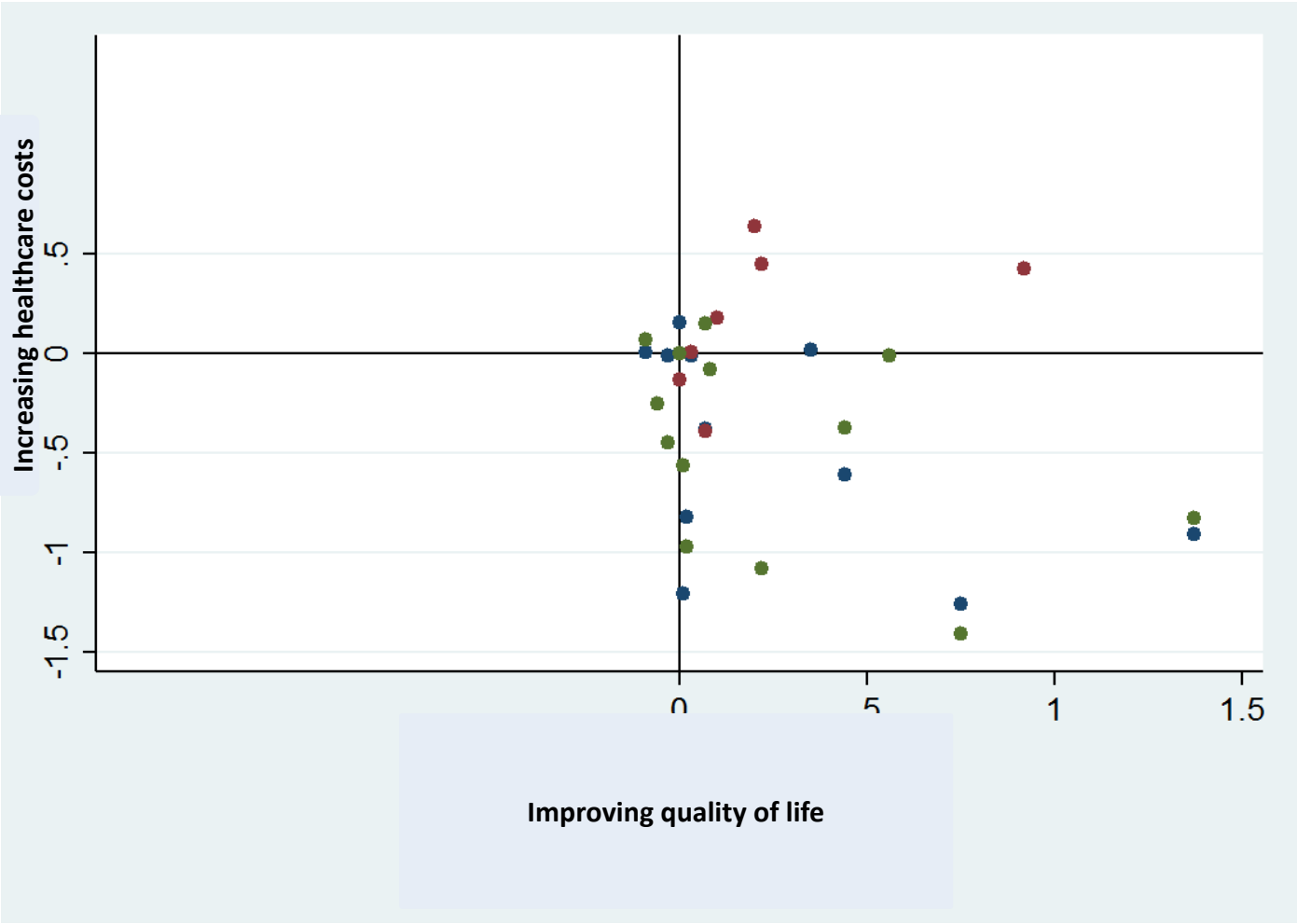
Figure 4 Permutation plot



Improving quality of life (axis x) and increasing hospitalisations (axis y blue), A&E attendances (axis y green) and total costs (axis y- red).

In this permutation plot, the effects of self-management interventions on outcomes (quality of life) and utilisation (hospitalisations and total costs) can be visualised simultaneously by placing them in quadrants of the cost effectiveness plane depending on the pattern of outcomes. Such plots identify studies in the appropriate quadrant (i.e. those that reduce costs without compromising outcomes) and those in problematic quadrants (i.e. those that reduce costs but also compromise outcomes, or those that compromise both outcomes and costs).

Figure 3

Click here to download Figure Figure 3 - cost Forrest plot.pptx

Figure 3 Meta-analysis of total costs